

Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions



Final

Project Code	ME1117
Project Manager	Rebecca Walker
Date	August 2010

Environment & Ecosystems Division Document Control

Title: Strategic Review of Offshore Wind Farm Monitoring Data
Associated with FEPA Licence Conditions

Submitted to:	Carly Brooks
Date submitted:	27 th July 2010
Project Manager:	Rebecca Walker
Report compiled by:	Rebecca Walker and Adrian Judd
Quality control by:	Adrian Judd
Approved by:	Stuart Rogers
Version:	Version 1.4

Version Control History			
Author	Date	Comment	Version
Cefas	1 st July 2009	Draft to be reviewed by steering group	Version 1.1
Cefas	11 th September 2009	Draft to be Defra peer reviewed	Version 1.2
Cefas	16 th February 2010	Final draft to be reviewed by MMO	Version 1.3
Cefas	27 th July 2010	Final draft	Version 1.4
Cefas	19 th August 2010	Final version	Version 1.5

Executive Summary

The ME1117 project has collated and strategically reviewed monitoring reports from ten wind farms, which are currently operational or under construction in English and Welsh waters. The aim of this desk-based review has been to summarise the monitoring undertaken at each site and to compare and contrast the monitoring and licence conditions between sites to distinguish between generic and site specific issues, identify comparability of datasets, to assess which conditions can be removed or require amendment, and where possible to forecast implications of identified effects for future Rounds of offshore wind farm development. Ultimately, this desk-based review was a first step in providing recommendations and a framework for future monitoring, and it is recommended that similar reviews be undertaken in the future as more data becomes available.

The benthos, fisheries, sediment processes and noise (Cefas), ornithological (FERA) and marine mammal (SMRU Ltd.) aspects of the monitoring reports have been reviewed. While there are site and topic specific issues and suggestions, it has been possible to formulate more general recommendations across the sector for future monitoring. It is concluded that it is vital to have clearer objectives within licence conditions to ensure the developer knows why and what monitoring is required. The importance of incorporating datasets from national or even international monitoring programmes to utilise all available data is highlighted and the need to develop novel techniques to assess the issues identified in the Environmental Statements is made. It has been recognised that few conditions can be removed from licences. Licence conditions also need to better reflect current scientific understanding and need to be more explicit in their wording to aid enforcement. More work is also required within monitoring reports to assess interactions between different receptors. Finally, all topic areas stressed the need to have a standardisation of survey and analytical methodologies wherever possible to aid in future comparison and assessment.

Contents

	Page
	2
Executive Summary	2
1. Introduction	5
1.1 <i>Context</i>	5
1.2 <i>Why Monitor?</i>	5
1.3 <i>Structure and Content of the Report</i>	6
2. Key Issues	8
3. Monitoring Similarities / Differences of Each Site	9
<i>Benthos</i>	9
<i>Fish</i>	9
<i>Coastal Processes</i>	10
<i>Noise</i>	10
<i>Birds</i>	11
<i>Marine Mammals</i>	12
<i>Conclusion</i>	12
4. Lessons Learnt from Interactions	14
<i>Benthos</i>	14
<i>Fish</i>	14
<i>Coastal Processes</i>	14
<i>Noise</i>	14
<i>Birds</i>	14
<i>Marine Mammals</i>	14
<i>Conclusion</i>	15
5. Recommendations for Removal of Licence Conditions	16
<i>Benthos</i>	16
<i>Fish</i>	16
<i>Coastal Processes</i>	16
<i>Noise</i>	16
<i>Birds</i>	16
<i>Marine Mammals</i>	16
<i>Conclusion</i>	17
6. Recommendations for Strengthening or Alteration of Licence Conditions	18
<i>Benthos</i>	18
<i>Fish</i>	18
<i>Coastal Processes</i>	19
<i>Noise</i>	19
<i>Birds</i>	20
<i>Marine Mammals</i>	20
<i>Conclusion</i>	21
7. Recommendations on the Need and Scope for Comparability in Datasets	22
<i>Benthos</i>	22
<i>Fish</i>	22
<i>Coastal Processes</i>	22
<i>Noise</i>	22
<i>Birds</i>	23
<i>Marine Mammals</i>	23
<i>Conclusion</i>	24

8.	Implications and Recommendations for Future Developments	25
<i>A</i>	<i>Generic Recommendations</i>	25
<i>B</i>	<i>Benthos</i>	26
<i>C</i>	<i>Fish</i>	26
<i>D</i>	<i>Coastal Processes</i>	27
<i>E</i>	<i>Noise</i>	27
<i>F</i>	<i>Birds</i>	28
<i>G</i>	<i>Marine Mammals</i>	29
9.	International Case Studies	31
10.	Conclusions	33
11.	Summary of Key Findings and Conclusions	35
12.	References	40

Annexes (available for download at www.cefas.co.uk)

Annex 1 – Benthos

Annex 2 – Fish

Appendix 2.1 – North Hoyle

Appendix 2.2 – Barrow

Appendix 2.3 – Lyn & Inner Dowsing

Appendix 2.4 – Kentish Flats

Appendix 2.5 – Scroby Sands

Appendix 2.6 – Burbo Bank

Appendix 2.7 – Gunfleet Sands

Appendix 2.8 – Rhyl Flats

Appendix 2.9 – Thanet

Annex 3 – Coastal Processes

Appendix 3.1 – Barrow

Appendix 3.2 – Burbo Bank

Appendix 3.3 – Lyn and Inner Dowsing

Appendix 3.4 – RAG Review of Round 1 sediment process monitoring data – lessons learnt

Annex 4 – Noise

Annex 5 – Birds

Appendix 5.1 – Site Summaries

Appendix 5.2 – Conformity to objectives across all sites

Annex 6 – Marine Mammals

Appendix 6.1 – Marine Mammals

Annex 7 – List of Documents Reviewed

Annex 8 – Key Findings and Conclusions

Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions

1. Introduction

1.1 Context

In the United Kingdom, licences under Part II of the Food and Environment Protection Act 1985 (FEPA) are required for any construction activity within the marine environment, or the deposition of materials at sea (aside from activities covered under the exemption order SI No. 1699 Deposits in the Sea (Exemptions) Order 1985).

The purpose of FEPA is to:

- Protect the marine environment, and the living resources which it supports and human health.
- Prevent interference with other legitimate uses of the sea.
- Minimise nuisance from the disposal of wastes at sea.

The Licensing Authority in England is the Marine Management Organisation (previously the licensing was the responsibility of the Marine and Fisheries Agency), in Wales it is the Welsh Assembly Government, in Scotland it is Marine Scotland and in Northern Ireland it is the Department of Environment.

It is an offence for any marine construction works, other than those exempted under Statutory Instrument Number 1699, to be undertaken without a valid FEPA licence. Part of the licensing process under FEPA is a thorough assessment of the likely effects of the works on the marine environment and the need for measures to mitigate impacts and/or provisions for marine environmental monitoring. To facilitate these actions conditions can be included within the FEPA licences. The licence and conditions are enforced by the Licensing Authorities and any failure by the Licence Holder to comply with these can trigger legal proceedings leading to prosecution if the licence holder is found culpable.

The main focus of FEPA monitoring is for site-specific issues, but the ME1117 project is intended to review the marine environmental monitoring in FEPA licence conditions to see what (if anything) can be extracted and applied to other sites, to review the utility of the licence conditions and investigate options for improving monitoring requirements.

This report has been prepared by Cefas with support from FERA and SMRU on behalf of Defra and the Marine Management Organisation.

1.2 Why Monitor?

Monitoring under FEPA is used for a variety of purposes. The main purpose of FEPA monitoring is to protect the marine environment, human health and to minimise nuisance or interference to other legitimate uses of the sea. Developers invest a lot of effort to produce Environmental Statements, the conclusions of which are often based on predictions derived from numerical models, extrapolation from site-specific and historic survey data and extrapolation from other analogous activities. However, there is a paucity of published peer-reviewed articles on the environmental impacts of offshore renewable energy devices (Gill, 2005) and only limited time-series data to monitor impacts.

Monitoring conditions can therefore be used to validate predictions made in Environmental Statements. An extension of this testing of predictions is to identify unexpected outcomes or impacts and, where appropriate, trigger the development of corrective actions. Given the limited base information, monitoring can also be used to deal with uncertainties within Environmental Statements by testing hypotheses on the nature, extent and duration of potential novel impacts. Overall monitoring is intended to investigate change relative to a defined “baseline” condition or set of parameters. This change could be: before and after construction; during construction with pre-construction; inside and outside the wind farm array; differences between seasons; differences between years; natural variation versus impacts from the offshore wind farm or any combination of these. Given these complex issues it is imperative that detailed rationales and hypotheses for the monitoring programmes are developed, i.e. what is being monitored and why, and which parameters will interact and why.

Monitoring is therefore an integral part of all FEPA licence conditions, but are the most robust, efficient and appropriate techniques and approaches being applied? To address this question ME1117 has reviewed the existing FEPA monitoring datasets to provide some preliminary recommendations. It should also be noted that inadequacies highlighted within the report have arisen due to the learning curve associated with the relatively new technology of offshore wind development and issues apply to both the developer (undertaking the monitoring) and Licensing Body (providing the licence conditions). As more sites are developed and more monitoring and research data becomes available further reviews will be necessary in the future.

To be fully effective, integrated approaches to monitoring programmes should be developed where inter-relationships and dependencies between sediments – benthos – fish – birds – mammals - noise are fully assessed. It is essential that monitoring programmes include temporal and spatial considerations (including interaction with other wind farm sites and activities).

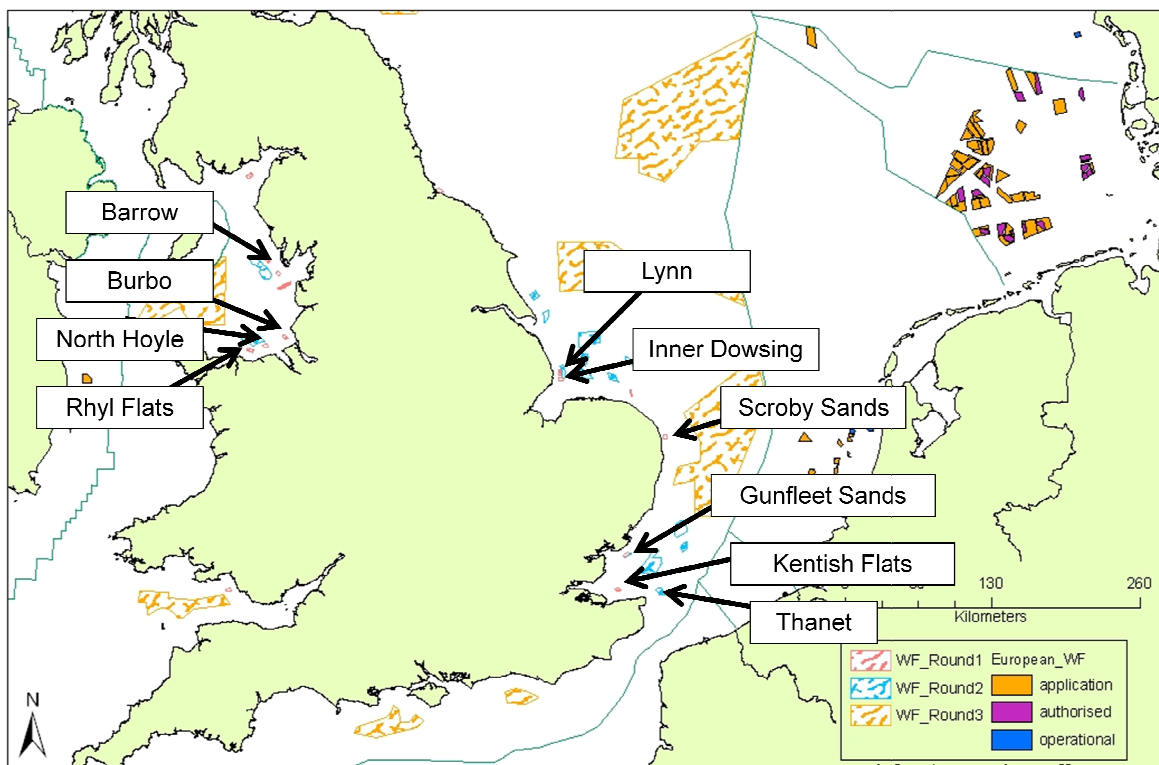
1.3 Structure and Content of the Report

Background information on the potential effects of offshore wind farms on six topic areas (benthos, fish, coastal processes, noise, birds and marine mammals) can be found in the relevant topic report in the annexes. However, this report seeks to draw out the key issues and conclusions from each topic area. The monitoring which was required in the licence conditions and which took place at each site is also detailed in each topic report contained within the annexes and their appendices. For this study the reviewers considered: the prediction and/or issue from the Environmental Statement; the associated FEPA licence condition; the baseline monitoring; during construction monitoring and the subsequent post-construction monitoring reports (where available). As part of the FEPA licensing procedure the Licensing Authority and their advisors check for licence condition compliance, appropriate use of sampling and analytical techniques, the robustness of conclusions, advise on revision to monitoring requirements as necessary and feedback into future licensing decisions. As such the ME1117 project is focussed on cross-site and industry wide issues. It should also be mentioned that not detecting an impact is not the same as there being no impact, only that there may not have been adequate statistical power to detect any effect. Therefore in terms of this report, we have only discounted issues where we have sufficient confidence to do so. Chapter 11 of this report summarises the key findings and conclusions of this review. It is provided as a quick reference guide indicating where responsibility for action rests but it does not repeat the detail and rationale from the preceding chapters which should be read in parallel to Chapter 11.

Ten wind farms were selected for review, which were either operational or under construction. However, it was the operational wind farms, which were reviewed in more detail, due to the availability of post-construction monitoring data.

- Barrow
 - Burbo Bank
 - Kentish Flats
 - North Hoyle
 - Scroby Sands
- } Operational
- Gunfleet Sands
 - Lynn
 - Inner Dowsing
 - Rhyl Flats
 - Thanet
- } Operational

Wind farm locations around the UK and neighbouring areas.



2. Key Issues

- The differences in monitoring between sites.
- The interactions between different receptors and wind farms.
- Recommendations on whether any conditions can be removed.
- Recommendations on whether any new conditions or approaches to monitoring/analysis should be adopted.
- Recommendation on the need and scope for comparability in datasets and reporting styles.

3. Similarities / Differences in Monitoring at Each Site

Benthos (including colonising epifauna)

There are both general licence conditions and further site-specific conditions applied to OWF benthic monitoring. As a standard, monitoring includes a pre-construction survey to provide a baseline for subsequent monitoring, a second survey during construction, and three more annual surveys on consecutive years following construction. Sampling requirements include consideration of:

- The sample locations for ongoing monitoring (including reference sites), determined by precise foundation locations, location of cables, coastal process modelling outputs and geophysical surveys.
- The sample number and replicates, as sampling should involve a minimum of three replicates at each station.
- Epifaunal colonisation of monopiles, determined by video observations and analysis with some accompanying sample collection for verification and identification.
- Inter-tidal sampling, to be undertaken at lower, mid and upper shore stations along three transects running perpendicular to the shore in the area of the cable landfall.

These licence conditions do vary on a site-specific basis, and while survey guidelines are available (Boyd 2002), survey techniques have varied across sites, sometimes in relation to these site-specific issues. Differences in survey methodology, therefore, limits full comparison between all sites.

To date none of the benthic monitoring has identified any detrimental effects, however, given the timescale of monitoring it is not possible to draw any concrete conclusions on the generic impact of offshore wind farms on benthos. N.B. The word 'detrimental' has been used, as the word 'significant' has a specific statistical meaning/inference, and we do not consider that current analysis has shown whether or not there are 'significant' effects. It may take a much longer time-span for these to become evident; hence we chose detrimental to indicate immediate large-scale changes attributable to the construction.

Fish

The wording of licence conditions on fish issues has evolved but in essence similar requirements have been applied to all licences. These are to:

- Provide technical specifications of the cables.
- Where electro-sensitive species are identified in the EIA, fish surveys have been requested to investigate distribution and abundance.
- To investigate fish aggregation device (FAD) effects, surveys have been requested inside and outside the wind farm to assess distribution and abundance.
- The appointment of a suitably qualified and experienced Fisheries Liaison Officer (FLO) and Fisheries Liaison Representative (FLR).
- Construction activities and surveys need to be agreed with the FLO.
- Notify mariners (including fishermen) of details and scheduling of construction and survey works.

Generally, while the conditions imposed are similar in nature, different target species at different sites has meant that methods and equipment has differed. For example, some developments have used existing data (e.g. beam trawl survey data from Cefas), whereas most have commissioned new surveys. Surveys have used scientific and/or commercial gears. Some have utilised anecdotal information from fishermen or other surveys whereas others have not. Some have undertaken broad scale surveys whereas others have been more targeted.

To date most fish surveys have proven useful in building up a picture of post-construction distributions of fish within and outside of the wind farm array. However, the short datasets currently available do not allow for any clear distinction between construction effects and the influence of natural variation in fish distribution and abundance. In addition, whilst monitoring reports describe the findings of the fish surveys, a detailed review of how these relate to construction activities is still lacking. Better integration with national data of trends in fish species may assist in assessing and monitoring impacts and aid in comparing effects across different wind farms.

Coastal Processes

Monitoring licence conditions for coastal processes are similar in nature, and are aimed at assessing:

- Suspended Sediment Concentrations (SSC) during pile installation and cable laying - from in-situ Optical Backscatter (OBS, bed-mounted or towed) and water samples, to monitor the short-term disturbance during construction.
- Seabed morphology and scour - from broad-scale pre- and post-construction bathymetry, particle size analysis (PSA) and high-resolution bathymetry from a subset of adjacent foundations to monitor seabed change both locally around individual turbines and across the wind farm as a whole.

Standardised methods exist for monitoring SSC and seabed morphology and scour, therefore comparability exists across different wind farm sites. However, monitoring strategies still have to be designed specific to the site conditions to ensure the locations chosen are suitable for the monitoring required. In general terms, across all sites, the SSC monitoring has upheld predictions made in the Environmental Statements, that impacts are both short-term and localised, both in terms of monopile installation and cable laying. The limited monitoring data available suggests that the natural dynamics and morphology of seabed features are largely unaffected by the construction of offshore wind farms with monopile foundations. The level of scouring (without scour protection) has so far been within those predicted within the ES. However, scour wakes, as a consequence of secondary scouring around scour protection, were not predicted in any of the Environmental Statements and this is a topic that requires further investigation.

Noise

Only eight of the wind farms reviewed had noise reports available. All eight of these wind farms (five operational wind farms; Barrow, Burbo, Scroby Sands, Kentish Flats and North Hoyle and three under-construction; Gunfleet Sands, Lynn and Inner Dowsing) have a requirement for underwater noise monitoring:

- Monitoring must be carried out each year for comparative purposes (i.e. pre-construction, construction, plus three years of post-construction monitoring).
- Measurements must be made at a variety of locations: immediately adjacent to the turbines; between turbines; within the array; outside the array at varying

distances from the turbines. These measurement sites should reflect differences in sediment type, water depth and foundation/tower type.

North Hoyle, Scroby Sands, Lynn and Inner Dowsing OWFs carried out pre-construction monitoring and obtained baseline measurements, which can be compared with each other. However, the remaining four wind farms either took ambient noise measurements during construction, during breaks in pile-driving activities (Burbo and Gunfleet Sands) or while only a few wind turbines were operational (Barrow), or did not undertake noise measurements at all (Kentish Flats). Construction noise monitoring took place for all eight wind farms and post-construction (operational) reports have been submitted for four out of the five operational wind farms (except Burbo, which used the post construction report of the nearby North Hoyle OWF), with all four wind farms carrying out one year of post construction monitoring. However, there is variation between the wind farms within the post construction monitoring (especially with regards to Kentish Flats), which makes them more difficult to compare, although all did collect and present detailed data on the frequency and magnitude of the underwater sound generated by their respective wind farms.

All licences were very similarly worded, with all licence conditions applicable to each wind farm. All sites followed similar methodologies, although the Lynn and Inner Dowsing sites followed a different (but comparable) approach. This has allowed comparisons to be drawn across the differing sites.

The most significant conclusions from the construction noise monitoring reports are that a) the sound generated during pile-driving activities is far higher than the ambient noise levels, and b) that propagation of this sound is quite variable. Both of these facts highlight the importance of a dedicated monitoring programme during the construction phases of OWF development: the current level of knowledge is not enough to predict the extent of the impact of construction noise on marine fauna, as the generation and propagation of the sound appears to depend on many, possibly interacting factors such as piling technique, bathymetry, water depth.

All of the underwater sound monitoring surveys carried out during the operational phase (Barrow, Kentish Flats, North Hoyle and Scroby Sands) showed that there was very little difference between the sound levels within the wind farm arrays and outside them.

Birds

It is clear that bird monitoring can be very site specific due to the presence (or lack of) of certain bird species at certain times of the year. However, a number of standard conditions can be applied to the licence and a typical licence generally requires the following:

1. One to two years of pre- and during-construction monitoring and three years of post construction monitoring.
2. An assessment of 'change of use' of the site, a reference site, and the surrounding area by birds
3. An assessment of the distribution of birds in the vicinity (sometimes specific species are stated) and in the wider environment.
4. An assessment of 'barrier effects'.
5. An assessment of collision risk and/or rate (sometimes conditional).
6. A requirement (sometimes conditional) for linking bird and benthic monitoring.
7. A requirement to consult with the Licensing Authority who will liaise with the

relevant statutory nature conservation agency.

The monitoring undertaken was generally of a high standard, both in terms of its ecological value and in terms of meeting, or attempting to meet, the licence requirements, at least for the main conditions. However, some conditions were objectives to be met, while others were merely guidance. Sometimes the details of monitoring methods were stated and at other times not. In one case (Burbo OWF) no objectives or guidance was given at all, but it was stated in the licence that the monitoring programme should be agreed with Natural England. In another case, Scroby Sands OWF, all the requirements were species (common tern) and site specific. No other general monitoring was required. On the other hand, no site or species specific conditions were identified for Gunfleet Sands, the requirement being to provide generic information on bird / wind farm interactions.

There were similarities between sites due to the fact that basic ornithological monitoring methodologies are standardised and set out by COWRIE guidance. However, for other techniques, such as migration monitoring and radar surveys, standardised techniques do not exist and therefore the developers devised their own methods and analysis techniques. In some cases, these data were then not used, which should not be encouraged given that these techniques are often required for meeting licence conditions, such as those for barrier effects, which cannot be met by the basic standardised monitoring methods alone.

Conditions one, two, three and seven above were always met at each site, as far as practically possible, however, points five and six were rarely met convincingly, as either the requirement was not triggered or the developer was unable to undertake the monitoring as the appropriate methods to address these conditions do not yet properly exist. The linkage with benthic monitoring was never met, as this requirement was never triggered and perhaps should be investigated in the future – especially as benthic studies are being undertaken as part of the monitoring process.

Marine Mammals

The five operational wind farms reviewed had very little or no monitoring requirements under the FEPA licence conditions. No marine mammal monitoring was required at North Hoyle and Kentish Flats and Barrow and Burbo had a single condition to minimise disturbance during pile-driving activities. However, the method to undertake disturbance minimisation was not defined and therefore differed for each site. Scroby Sands had different requirements again, and did not require disturbance to be minimised during piling activities, however, did call for seal monitoring during the pre- during and post-construction phases. Of the wind farms under construction, the Lynn and Inner Dowsing licence conditions only required disturbance to be minimised during piling activities and did not require any other monitoring. However, after concerns were raised by NE and DEFRA, a Marine Mammal Monitoring Protocol (MMMP) was produced and adopted by the developer, which included the use of soft start techniques in conjunction with Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Systems (PAMS). All wind farms, which reached the construction phase after Lynn and Inner Dowsing, appear to have much more thorough and detailed licence conditions, with similar marine mammal protocols to be implemented, although the data for each was not available for review at this time.

Conclusion

Both benthos and fish monitoring licence conditions are very similar across each wind farm licence, however, different site-specific conditions, such as the target species, has ensured

that different equipment and methods have been utilised during the surveys. Using national data sources and trends within these analyses may aid in comparison of surveys across wind farm sites.

Coastal processes monitoring can be easily compared across sites, as standardised methods are employed to carry out these surveys.

A combination of very similar licence conditions and predominately one company carrying out the noise monitoring and analysis has ensured there is a degree of comparability across sites.

Basic standardised ornithological monitoring was carried out across the sites, allowing a degree of comparability (e.g. boat-based and aerial transects). However, to meet other licence conditions such as investigation of barrier effects or collision risk, further techniques are required (e.g. motion sensitive still/video cameras, infra-red cameras, thermal imaging, X-band radar), which have been left to the developer to devise, hence these are generally site specific and not comparable.

With regards to marine mammals, initially very little was requested of the developer, and while there was a licence condition requiring a minimisation of disturbance, the condition was vague and allowed multiple interpretations, resulting in a lack of similarity in methods and data produced. However, primarily as a result of the introduction of MMMPs, the more recent wind farms (those which are under construction at the present time) have similar monitoring conditions. To enable further comparisons to be drawn across sites, these should be made generic, incorporating essential monitoring detailed in the marine mammal report in the appendices, as well as allowing for site specific requirements.

4. Lessons Learnt from Interactions

Benthos

Overall very little has been done within the monitoring reports to assess interactions between benthos and other environmental parameters. To address this, improvements could be made in all monitoring programmes to better address ecosystem issues by investigating relationships between sediment, benthos, fish, bird and marine mammal monitoring outputs.

Fish

As for the benthos monitoring, very little has been done to assess interactions between fish and other environmental parameters. Again, improvements could be made in all monitoring programmes to better address ecosystem issues by investigating relationships with other aspects of the ecosystem (e.g. sediments and benthos) . Survey reports focus on species of conservation or commercial importance, but the ecological importance of other species, e.g. as prey, is rarely considered.

Coastal Processes

As for the benthos and fish monitoring, very little has been done to assess interactions between coastal processes and other environmental parameters. Again, improvements could be made in all monitoring programmes to better address ecosystem issues by investigating relationships between sediment, benthos, fish, bird and marine mammal monitoring outputs.

Noise

All but one report discussed the potential interactions between underwater sound propagation and marine mammals and fish. There have also been short discussions on the interactions between pile diameter and water depth on underwater sound propagation. However, none of the reports addressed any interaction between habitats and sound. One post-construction monitoring report (North Hoyle) stated it would look at interactions between noise, benthic ecology, fish monitoring and epifaunal colonisation surveys, however, this report is not available for review as yet.

Birds

No discussion on the interactions between birds and fish or invertebrates has taken place. The North Hoyle licence had a condition to investigate the links between bird and invertebrate numbers, but this was conditional on finding a decline in common scoter, which was not observed. Overall, limited reporting was evident to analyse the linkage between bird and invertebrate numbers, even though prey levels might be an important explanatory variable for bird numbers within a development.

Marine Mammals

Very little can be deduced from the monitoring reports due to a lack of long-term marine mammal monitoring data. More recent FEPA licences do include scope for longer term monitoring, but this is poorly defined and therefore it is not enforced as a licence condition. It may be appropriate in future, when further data is available, to require relationships between variables to be investigated, especially with regard to marine mammals and fish/invertebrate prey.

Conclusion

Very little has been done within the monitoring reports to assess interactions between the benthos, fish, coastal processes, birds and marine mammals or any other environmental parameter. Data does exist, for example, with regards to benthic invertebrates and bird monitoring, but this has not been utilised so far.

Only the effects of underwater noise on marine mammals and fish have been looked at in any detail. Post construction monitoring for North Hoyle proposed to investigate interactions with noise, benthic ecology, fish and epifaunal colonisation, however this report was not available for review.

5. Recommendations for Removal of Licence Conditions

Benthos

The benthos monitoring conditions have followed a standardised format with slight modifications over time. The monitoring prescribed within the FEPA licence is still required, however, a reduction in the frequency of infaunal monitoring, over a longer period of time with the incorporation of more regional based monitoring/assessment should be considered.

Fish

It is not possible to conclude that any impacts on fish have been demonstrated to be negligible and therefore to recommend that conditions can be removed. Further work would first be required and this may become apparent when more datasets become available.

Coastal Processes

The results of suspended sediment concentration (SSC) monitoring indicate that, for monopile foundations only, such monitoring need only be requested in locations where sensitive receptors (e.g. seagrass beds, fish spawning locations) may be present. As such, the requirement for SSC monitoring can be determined on a site-specific basis.

Research has also taken place to show there is no need to monitor waves for diffraction/interference effects of monopile structures (Cefas, 2005).

Noise

The propagation of underwater noise is site specific as it is influenced by many factors, which can have both solitary and cumulative effects on the propagation of the sound. However, given that several sites have shown that the noise generated during the operational phases of the wind farm are only slightly elevated above background ambient noise levels, it may not be necessary to undertake three years of post construction (operational) noise monitoring. It is of course, still important to carry out some operational noise monitoring, dependant on the site specific nature of underwater noise propagation and a reduction to a single monitoring event is recommended.

Birds

The general licence conditions that are present are important in determining the distribution of birds within the wind farm area, and any change of use due to wind farm construction. Site-specific conditions are put in place due to birds of conservation concern. Both the standard conditions and those site specific conditions should not be removed at the present time as potential impacts to avifauna remain a concern, and can only be considered for removal when baseline monitoring suggests birds are unlikely to be affected. The requirements for barrier effect monitoring and collision risk/rate monitoring have generally found little significant effects, but this may be because the monitoring techniques are less well developed. In any case, these issues are still a concern for regulators and conservation bodies, and should not be removed.

Marine Mammals

Marine mammal monitoring has evolved over the development of Round 1 and Round 2 wind farms, from no monitoring required to the introduction of MMMPs. Further development is still required, therefore it is felt that no conditions should be discarded at the present time.

Conclusion

No fish, bird or marine mammal monitoring conditions can be discarded at this stage given the datasets presently available. However, a reduction in the frequency of benthic infaunal monitoring with the incorporation of more regional based monitoring/assessment should be considered. In addition, the requirement to monitor SSC should be determined on a site-specific basis and there is also no need to monitor waves for diffraction/interference effects. It is also recommended that further consideration is given to the duration of operational noise monitoring (i.e. one instead of three years).

6. Recommendations for Strengthening or Alteration of Licence Conditions

Benthos (including colonising epifauna)

Monitoring has shown that so far, no detrimental effects of OWF on the benthic environment have been detected. However, detecting change over this relatively short time scale, notwithstanding the large natural variability that can be experienced, has been difficult. This emphasises the importance of long-term data, and the limitations of obtaining suitable baseline (pre-construction) data under the existing licensing regime, which only requires one baseline survey and thus is unsuitable for determining temporal change. To address the limitations in obtaining detailed temporal baseline data and to give an understanding of natural variability, consideration should be given to incorporating national monitoring programmes (e.g. UKMMAS), and co-ordinated regional assessments (possibly based around the Crown Estates Round 3 proposals for Zonal Assessment Plans) into monitoring regimes. The addition of such methods gives the potential to alter benthic monitoring requirements, to a programme of less frequent, but longer term monitoring, although some more frequent monitoring concentrating on the known near-field and colonisation impacts will still be required.

The long-term effects of epifaunal colonisation of monopiles are still unknown. The observed increase in biomass associated with those organisms colonising the sub-sea structures, is likely to have long-lasting and far-reaching effects on the surrounding benthos. The long term effects of epifaunal colonisation will require monitoring and/or further research to address issues of concern, such as their potential as 'stepping-stones' for invasive species. 'Stepping stones' could allow the spread of invasive species, while the introduction of significant matrices of hard substrate would potentially allow such species to become established and have local and regional effect. This is mediated not by solitary individuals occurring here and there, but much further down the colonisation process where a population develops in a local area and out-competes the native residents. For example, horse mussels would originally require a hard substrate to settle upon, but they themselves are hard substrates, so provide further potential for colonisation and alteration to the native environment; to the extent that a mussel beds could spread over extensive areas of soft substrate, well away from individual monopiles, once they have a foot-hold. It is worth noting that three species never previously recorded in Danish waters were observed at the Horns Rev offshore wind farm, with the crustacean *Jassa marmorata* recorded in very high numbers (close to one million individuals per meter squared) covering the upper sublittoral zone on the monopiles, down to the scour protection. There is a dual interest, both in monitoring the spread of invasive species and in their rate of population growth at locations where they have been found. While the issue of 'stepping-stones' was discussed at the Offshore Energy SEA Expert Assessment Workshop, the above points do not appear to have been addressed. This is also an important consideration under the Marine Strategy Framework Directive and development of the Good Environmental Status Descriptor for Non-indigenous species.

Fish

The fish monitoring data is not currently providing results sufficient to provide definitive cause and effect conclusions and outputs show a need to develop more novel approaches to fish monitoring, so that assessments can be made in the context of other influences. In addition to this a more targeted approach to monitoring should be considered, including monitoring over several sites to give better spatial coverage and giving a greater importance to temporal variability. Longer time series or spatial extent for surveys may also add value to these surveys, although greater co-operation between developers would

be required for this to work. The requirements on spawning ground surveys should be applied as standard in areas where restrictions on construction activities are included within the FEPA licence conditions.

It is not always apparent from the monitoring reports that the developers have a clear understanding of why they are undertaking fish monitoring, which may account for some choices made within the monitoring process. Licence conditions should perhaps be made more explicit to describe why an issue is important and why it needs to be monitored.

As ongoing research is being undertaken with regards to wind farms and their effects on the marine environment, licence conditions need to be reviewed to ensure they reflect current understanding and consideration given to the need for future research or mitigation measures.

Coastal Processes

Wherever morphological studies are undertaken, the adoption of multibeam surveys as the preferred methodology to measure change from scouring and cable laying is recommended.

As chapters five, six and seven of the “Guidelines for the conduct of benthic studies at aggregate dredging sites, produced for the Department for Transport, Local Government and the Regions, May 2002” is considered to be directly transferable for undertaking seabed surveys, licence conditions should take account of the revision to this document, to be published in 2010.

On site disposal of drill arisings (especially chalk) could be an issue at some sites. Release of chalk arisings in a low energy (and hence low suspended sediment environment) may have wider impacts to marine organisms. At present site specific solutions will have to be investigated taking into account the full range of options.

Impacts on seabed morphology from construction activities, such as jackup legs need to be highlighted, as these depressions/scour pits can be the same size as those from monopiles.

Noise

Despite the requirement for a pre-construction baseline survey, the data collected has been variable and it can be argued that only four of the eight wind farms carried out a true baseline survey. It is not possible to strengthen this condition, however, more stringent enforcement is required and the development of a standard methodology for baseline surveys would also assist in compliance.

Similarly, another condition requires sound measurements to be taken immediately adjacent to, between turbines and at various distances outside them. Certain wind farms developers did not take all these measurements and while these could have been due to safety reasons, no explanations were given. If this is due to safety issues, there perhaps is a need to alter the licence condition to allow standardisation of the data collected. In any case, greater enforcement of this condition is required.

In light of the findings of the monitoring reports, which suggest that the construction phase is the least predictable and potentially most harmful to marine life, it may be advisable to strengthen conditions relating to monitoring during the construction phase.

There is also a necessity to investigate the interactions between noise propagation and the local environment (such as sediment type, water depth and bathymetry) as all these variables can affect the noise levels. This data could be easily collected, therefore an additional licence condition requiring this data is suggested. Another addition could be the requirement to examine the noise data in relation to the marine mammal, benthic and fish reports to gain a more holistic view of the effects of underwater noise and its interactions with other variables, as described in Section 5.

Birds

As previously discussed in Sections 3 and 5, the monitoring conditions associated with barrier effects and collision risk resulted in monitoring of a lesser standard and these conditions were generally not met, but this may be due to a lack of techniques available. The Licensing Authorities should give more detailed guidance on these conditions as to the methodology to be followed and should continue to request trials of new techniques to quantify effects (e.g. motion sensitive still/video cameras, infra-red cameras, thermal imaging, X-band radar). Ultimately however, if techniques are not yet available, further work is needed to better evaluate barrier effects and collision risk.

As for other environmental parameters, the linking of benthic, fish and bird monitoring was rarely undertaken. Ecosystem interactions are an important consideration to understanding population level effects (e.g. predator = prey relationships) so this condition should be more strongly enforced by the Licensing Authority.

Marine Mammals

The further development of MMMPs to include the use of trained and dedicated Marine Mammal Observers and concurrent use of PAM is recommended. There is also the potential to develop the use of alternative detection techniques such as infrared scanning technology. There are concerns about monitoring during poor weather conditions, as acoustic methods such as Passive Acoustic Monitoring (PAM) does not detect seals and will not detect cetaceans if they are not vocalising. Therefore it is suggested that in certain situations where seals or species of cetacean may be present and remain undetected if only visual monitoring or only PAM is carried out, piling should not commence at night or in poor weather, as suggested by 'best practise' in the new JNCC piling guidelines (2009).

It is recommended that an exclusion zone is defined by FEPA conditions, either based on the frequency and level of noise, the hearing thresholds of the species in the area and an agreed acceptable received noise level, or using the minimum 500m zone as suggested by the JNCC (2009). FEPA licence conditions should also define soft start methods more thoroughly, specifying conditions where re-drives occur and including improvements in protocol as recommended by RPS Energy in their 2008 Lynn and Inner Dowsing report.

Site-specific MMMPs are recommended to tailor monitoring to the target species of the area. However, it should still be possible to standardise the method of recording animal sightings, group size, behaviour etc, to enable comparisons across different sites. More importance should be given to baseline or pre construction monitoring as this will be the reference data, if post construction monitoring is required. For Annex II species in certain areas (e.g. in the sea area adjacent to existing seal SACs, or areas of frequent use by bottlenose dolphins), knowledge of habitat use of the area should also be developed for baseline / pre-construction monitoring to complement abundance monitoring as this type of data is of value in determining the importance of the area to that particular species.

Conclusion

Benthic monitoring conditions should give consideration to incorporating national monitoring programmes and co-ordinated regional assessments. These may be based on regional monitoring programmes such as the regional environmental characterisations undertaken by the UK aggregates industry; the Crown Estate's Round Three proposals for Zonal Assessment Plans, into monitoring regimes, which could potentially reduce benthic monitoring frequency but undertaken over a longer duration. The long-term effects of epifaunal colonisation of monopiles require monitoring as these effects are still unknown and could have long-lasting and far-reaching effects on the surrounding benthos.

Fish licence conditions should be updated as scientific knowledge improves. They should also become more targeted to interpret more cause / effect conclusions. Conditions should also be made more explicit to ensure developers understand the need for monitoring and carry out appropriate surveys.

Coastal processes monitoring conditions should be reviewed with regards to the revised benthic survey guidelines to be published in 2010. Potential conditions need to be devised to monitor the possible impacts from on site drill arisings and the impacts on seabed morphology from other construction activities.

With regards to noise monitoring, there is a need for stricter enforcement of the licence conditions as well as a strengthening of construction conditions as these are not currently reinforced in the detailed conditions as occurs for the operational monitoring. Potential new conditions include the collection and analysis of local environmental data and the comparison with other monitoring reports.

Development of guidance in ornithological monitoring techniques to include assessment of barrier effects and collision risk should be undertaken, this can build on the work by COWRIE on the use of aerial surveys to detect bird displacement (COWRIE 2007).

There are several recommendations for marine mammal monitoring, both for baseline/pre-construction monitoring and for construction monitoring. Overall, licence conditions have improved dramatically over the development of the Round One and Round Two wind farms, although there is still further scope for improvements prior to Round Three. A standard set of monitoring protocols would also aid cross-site comparisons.

7. Recommendation on the Need and Scope for Comparability in Datasets and Reporting Styles

Benthos

Statistical analyses within the monitoring reports do not always appear to be consistent or correct, and can raise questions on the validity of conclusions. Discussions are being undertaken between Cefas / NE / JNCC and CCW on the best way to undertake these analyses and make better use of available data, such as Environmental Assessment Reference Stations (EARS), within monitoring reports to add to the body of data for the area and to more fully understand the natural variability of the area. Incorrect analyses at one site mean that future cross-site or cross-study comparisons are reduced to the lowest common denominator in analytical quality. It is therefore imperative that an adequately qualified and experienced analyst conducts the data analysis and interpretation. It is recommended that a QA/QC procedure is employed on data analysis and supplied with the monitoring reports.

The objectives of benthic monitoring should be stated clearly at all stages, with clear testable impact hypotheses. Monitoring should also be specifically tailored to the predictions made in the EIA and address the licence monitoring conditions.

Fish

Surveys have used a variety of gear types due to site-specific conditions. However, it is clear that in some cases inappropriate gears have been used, e.g. beam trawls have been used inappropriately to try and survey pelagic species. This leads to the under-representation of fish assemblages and makes any comparisons between sites difficult.

Monitoring reports have been variable in quality, and as previously mentioned in Section 6, it has become apparent that some developers do not understand why they are undertaking fish monitoring. It would be useful for the reports to have a more standardised format, detailing what was undertaken, why it was undertaken, and how the licence conditions have been met.

Coastal Processes

Consistency between repeat surveys is crucial and this has not always occurred for the coastal processes monitoring (e.g. for repeat suspended sediment surveys / analysis).

There has also been little conformity in reporting style and format, or in standardisation of approaches undertaken. As for the fish review, guidance on reporting style and requirements may aid future assessments and reviews of cross-site issues.

Noise

The noise monitoring reports were generally confusing, with some information contained within the relevant report and other information contained within the overview report. In addition, in none of these OWF reports was it possible to find out exactly what/where measurements had been taken. Charts were often the best indication of where measurements were taken in relation to turbines, but these rarely showed a scale or bathymetric information, and never both sets of information.

Charts showing measurement locations (with reference to the OWF if applicable), local bathymetry, with a scale and latitude/longitude, would be a useful addition, in combination with a table detailing metadata (an example is given in Table 1).

Table 1: Example of table to be included in monitoring reports.

Measurement Station	Date	Location			Water depth (m)	Distance from ref. point (m)	Sediment type?*	Time of day	Sea state	Wind speed	No. operational turbines (if applicable)	Turbine velocity	Shipping traffic observed?
		RE: array	Lat.	Long.									
A		Outside											
B		Outside											
C		Between turbines											
D		Between turbines											
E		Etc.											
F etc.													

* This data be obtained by carrying out grab samples and PSA

A common chart / metadata table would also allow for easier comparison of data across sites.

As for the fish monitoring reports, it would be useful if the reports were written up with a view to explaining how they have approached, and how they have fulfilled (or not) the various licence conditions, i.e., writing the report to answer the questions rather than writing, or referencing, a report and assuming the answers will be drawn from it.

Birds

Basic ornithological monitoring follows a standard set of methodologies laid out by the COWRIE guidance, hence these methods can be easily compared pre- during and post-construction as well as across sites. However, for other techniques such as migration monitoring, standardised techniques for offshore environments do not exist, therefore it has been left to the developer to design such techniques, which has meant these methods and results are not as comparable across sites. The production of standardised methodologies is the best way to address this problem, the Guidance on Methods for Monitoring Bird Populations at Onshore Wind Farms may provide a useful starting point (SNH 2009).

Many reports contain large volumes of almost raw data, anecdotal observations and short textual summaries. A better summary of this data would be of help to a reviewer. The same information is often repeated, but with a slightly different stress for different reasons and this is also a drawback of these reports. A full executive summary to date for each year of reporting would aid review, as would a clear and explicit assessment of how the licence conditions will be addressed and how they have been met. In addition, for some developments, different consultants were used in different years to investigate the same issue, resulting in inconsistency in reporting style and therefore hindering comparability between years.

Marine Mammals

Currently, it is not possible to properly compare the data sets from each wind farm, as data were collected in a variety of ways and not recorded in a standardised format. In addition, a standard set of monitoring protocols has not yet been developed, which would aid in cross-site comparison.

Conclusion

The main issue with the benthos monitoring reports was variability and application of suitable statistical analyses. The reports also needed to state objectives of the benthic monitoring at all stages, and address licence conditions and predictions made within the ES.

The fish monitoring reports were not often comparable across due to differences in gears used. The reports were confusing, with no clear direction on reasons for sampling. The reports should provide an overview of what work has been undertaken and how this work meets the requirements of the licence conditions.

The noise monitoring reports were often confusing and could be easily improved with the addition of a chart detailing location, bathymetry, and a scale, together with a table detailing metadata.

As for noise monitoring, while the bird data was comparable between sites, the reports were often confusing and did not summarise how licence conditions were going to be addressed and objectives met.

Cross-site comparison of marine mammal datasets is not possible until there is a greater standardisation of survey and reporting methods.

8. Implications and Recommendations for Future Developments

Round 3 wind farms will be considerably larger than the Round One and Two wind farms. Larger wind farms may therefore mean a longer construction period. Differing technologies may be used due to increased water depths and other environmental factors and therefore the impacts on flora and fauna may be larger, or different species may be affected, with cumulative effects becoming more important, when considered with other wind farm projects and other human activities.

A. Generic Recommendations

These recommendations should apply to all monitoring, thus have been omitted from the topic specific recommendations.

- A.1 Generic conditions have been demonstrated to be useful, but it is important that the use of these is carefully managed so that site-specific issues are not overlooked.
- A.2 Improvements to the monitoring programme should be undertaken, to investigate relationships between the benthos, sediment, fish, bird, marine mammal and noise monitoring.
- A.3 Consideration is given to incorporating national monitoring programmes (e.g. UKMMAS), and co-ordinated regional assessments (possibly based around the Crown Estates Round 3 proposals for Zonal Assessment Plans) into monitoring regimes
- A.4 To aid enforcement, wording of some licence conditions should be altered (for example from “should” to “must”) or a more strict approval process from the Licensing Authority may be necessary.
- A.5 Licence conditions should be made more explicit to describe why an issue is important and why it needs to be monitored (i.e. tailoring the monitoring to predictions made in the EIA). Reporting should then follow this procedure, detailing what work has been undertaken and how this work meets the requirements of the licence conditions.
- A.6 Licence conditions should be reviewed to reflect current scientific understanding, with consideration given to the need for future research or mitigation measures.
- A.7 There should be a development of a standard methodology for baseline surveys, to assist in monitoring compliance, however, monitoring surveys must not be perceived as a standardised ‘one survey fits all’ approach.
- A.8 A QA/QC procedure is employed on data analysis and supplied with the monitoring reports.
- A.9 A better standardisation and planning of surveys is required to test hypotheses and lead to more focused and robust monitoring conclusions.
- A.10 Statement of where deviations from, or non-fulfilment of, conditions have been agreed with the Licensing Authority.

B. Benthos

Key effects of wind farm development on benthos include:

- Disturbance and habitat changes.
- Effects of construction and operational noise and vibration.
- Colonisation of the piles.
- Contaminants.
- Changes in the hydrodynamic regime and sediment transport patterns.

The benthos review has highlighted several issues and recommends:

- B.1 By developing recommendation A.1, there is potential to alter benthic monitoring requirements to a programme of less frequent, but longer term monitoring. Consideration should be given to whether this may also be appropriate for other receptors.
- B.2 Further work / monitoring of the long-term effects of epifaunal colonisation of monopiles should be undertaken.
- B.3 A qualified and experienced analyst should conduct the benthic data analysis and interpretation.
- B.4 The objectives of benthic monitoring and the test hypotheses should be stated clearly at all stages. Monitoring should also be specifically tailored to the predictions made in the EIA and address the licence monitoring conditions.

C. Fish

Issues identified in Environmental Statements and highlighted during their consultation, include:

- Effects of electromagnetic fields on electro-sensitive fish.
- Effects of construction and operational noise on fish.
- Fish aggregation effects.
- Interference/Displacement of fishing activity.
- Habitat changes.

The FEPA licence conditions for fish relate to these issues on a site-specific basis. Whilst the issues have been consistent between sites, different approaches to surveys have been applied largely driven by the data availability for individual sites and the relative importance of the area for conservation or commercial fish species. Recommendations are:

- C.1 Develop more novel and targeted approaches to fish monitoring, so that assessments can be made in the context of other influences.
- C.2 The requirements for spawning ground surveys should be applied as standard in areas where restrictions on construction activities are included within the current FEPA licence conditions or highlighted within the ES. The nature of such surveys will be determined on a site specific basis, but could include one or more of the following: larvae, maturity status, adult distribution and/or seabed surveys.

D. Coastal Processes

Issues identified for coastal processes include:

- Levels of suspended sediments.
- Seabed morphology changes.
- Scour and wake effects.

In addition to the conclusions provided in the “Review of Round 1 sediment process monitoring data – lessons learnt”, which was published in 2008 and is attached as Appendix 3.4 to the coastal processes review appendix, the main coastal processes recommendations are:

- D.1 There is a need to be more specific about monitoring locations, to ensure that the locations chosen are capable of recording/eliminating wind farm induced changes.
- D.2 Methodologies for suspended sediment analysis should be strengthened to allow for comparability within and between sites.
- D.3 Swathe bathymetry (multibeam) monitoring should form an integral part of the surveys for all offshore wind farms.
- D.4 Monitoring of scour wakes are currently not reported in detail and further work should be undertaken.
- D.5 On site disposal of drill arisings (especially chalk) could still be an issue at some sites and should therefore be investigated in more detail. Release of chalk arisings in a low energy (and hence low suspended sediment environment) may have impacts on the surrounding environment.
- D.6 Impacts on seabed morphology from construction activities such as jackup legs need to be highlighted as the depressions / scour pits can be the same size as those from monopiles, although temporary.

E. Noise

Issues identified for noise include:

- Effects on marine mammals.
- Effects on fish.
- Noise propagation.

The main issues that have been brought up by the noise review are the level of enforcement of the existing licence conditions, and the style and format of the monitoring reports. The main recommendations are as follows:

- E.1 It may no longer be necessary to carry out post-construction (operational) monitoring for three years and this condition could be downgraded to a non-standard condition, to be assessed on a case by case basis.

- E.2 It would be advisable to strengthen existing conditions relating to the monitoring and reporting of sound generated during the construction phase of OWF developments.
- E.3 It would also be advisable to reinforce the importance of analysing interactions between underwater sound generation and propagation with local environmental conditions and habitats, and to achieve this by using reports from the marine mammal, benthic and fish monitoring surveys.
- E.4 The reporting of the monitoring surveys needs to be clearer and more comprehensive. A template report, whereby licence conditions are discussed in terms of the approach and fulfilment of them might help, as would some kind of checklist.
- E.5 Better reporting style (in terms of charts, tables etc.) would be useful, as would including an appendix with a comprehensive list of data collected/existing in datasets.

F. Birds

Issues identified for birds within environmental statements include:

- Change of use of the site.
- Noise.
- Barrier Effects.
- Collision risk / rate.

Overall, the bird review has shown a good conformity to the basic monitoring requirements. However, conditions relating to barrier effects, collision risk and the linkage between bird and benthic monitoring have not been so well met. Reporting style is often confusing and could be improved by summaries detailing how licence conditions were approached and fulfilled. Recommendations are:

- F.1 All conditions to remain, with certain conditions being more strictly enforced.
- F.2 Standardised methodologies are developed for all aspects of ornithological monitoring to provide guidance to developers.
- F.3 If such methodologies do not yet exist, either the developer or research programmes should start to design these methods.
- F.4 A full summary to date for each year of reporting to be provided, including an explicit assessment of how licence conditions will be addressed and how they have been met.
- F.5 Mitigation measures as per marine mammals?
- F.6 Need to agree for individual species, the threshold level which would trigger adaptive management should an unforeseen (or greater than predicted) impact be detected
- F.7 The barrier effect can be a significant issue in certain locations and for certain species it should continue to be a condition of consent

F.8 Collision risk monitoring technology should be developed

F.9 More guidance should be provided on what level of change is required to trigger management action.

G. Marine Mammals

Issues identified for marine mammals include:

- Noise.
- Changes in habitat use.
- Pollution.

Round 3 wind farms will be considerably larger than the Round 1 and 2 wind farms. More species of marine mammal may be affected and/or larger numbers (including the poorly studied offshore species) and cumulative impacts may become more important, with other wind farm projects and other human activities taking place. Current mitigation approaches may also require adjustment, especially to address combined effects of noisy activities taking place at more than one site. Recommendations are:

- G.1 Well designed pre, during and post construction monitoring are important for some species in order to be able to assess the impact of the development on marine mammals and test predictions made in the EIA, in addition to making best use of existing information as appropriate. In certain situations, regional information may be sufficient for pre-construction baseline for the more intensive monitoring of disturbance effects during construction, but regional information will have less power to detect change, which may be pertinent to post-construction monitoring studies.
- G.2 The purpose of a monitoring plan needs to be established at the planning stage as it will affect the methodologies used (e.g., scale, frequency, duration) and be linked to the EIA predictions and licensing decisions (e.g. allowing for pile driving to take place in some areas/times).
- G.3 Regulators need to ensure the protocols and methodologies used to collect data are defined and standardised across regions, so adequate data are collected and are comparable across sites, despite variability in site conditions.
- G.4 New engineering designs (gravity foundations / floating platforms) and novel mitigation methods should be investigated, to minimise and mitigate noise disturbance associated with pile driving.
- G.5 Emphasis and research are required to test the efficiency of existing mitigation methods (soft starts) and develop more mitigation strategies to deal with newer technologies. The efficacy of 'soft starts' needs to be assessed in particular and the use of these procedures should be carefully documented and reviewed at a later date.
- G.6 Studies, which may involve observation, telemetry and photo-id should be conducted at sites thought to be particularly important, to determine the behaviour of relevant species, and the use they make of it for particular

activities associated with their life cycles. This baseline data will be important in establishing appropriate mitigation measures.

- G.7 There is the need for regulators to agree a defined marine mammal exclusion zone for each development and acceptable anthropogenic noise levels (as in the JNCC, NE and CCW Guidance on the Protection of Marine European Protected Species from Disturbance and Injury).
- G.8 Noise measurements taken during all stages of development should be incorporated into marine mammal data analysis.
- G.9 FEPA licences requirements for marine mammal monitoring are predominately concerned with the construction phase only (with the exception of Scroby Sands). The only conditions relating to pre/post construction monitoring leave it to the regulators and statutory consultees, such as NE and JNCC, to ensure further monitoring is undertaken *if deemed necessary*.
- G.10A clear reporting methodology is vital for efficient communication and in turn efficient mitigating actions if required.
- G.11 Marine mammal data collected at wind farm sites should go to a central repository where it can be accessed easily, i.e. Cowrie.
- G.12 Licence requirements for Round 3 should take into account results of monitoring data yet to be collected at Round 2 sites. A review of Round 2 monitoring data should take place in 1-2 years.
- G.13 More MMO's and PAM operatives will be required for the longer term piling operations expected in future wind farm developments,.
- G.14 There are limited mitigation measures to protect seals and further research is needed to assess the efficacy of these (for example, Acoustic Deterrent Devices and soft starts) and new methods should be investigated as appropriate.
- G.15 Noise monitoring data collected from previous wind farm construction and site specific noise propagation studies should be used to estimate expected noise levels and mitigation measures adapted accordingly (e.g., in estimating or extending exclusion zones).
- G.16 'Enhanced acoustic monitoring' is useful for pre, during and post construction monitoring, especially during poor weather conditions as it is the only mitigation method currently available. However, it has limitations as it will not detect seals or non vocalising cetaceans. The meaning of 'enhanced acoustic monitoring' also needs to be better defined.
- G.17 It is recommended that piling takes place only at night if it commences before nightfall i.e. when the MMO has had sufficient time to monitor the area visually to ensure there are no marine mammals in the vicinity.
- G.18 It must be made clear whether mitigation measures apply to other large marine animals such as basking sharks and turtles, which need to be developed and applied on a site specific basis.

9. International Case Studies

Further work is needed to better relate monitoring from other countries to UK scenarios wherever this can be demonstrated to be relevant. Therefore this section only provides a very limited overview for certain parameters. However, further information from other countries concerning current understanding and experiences in environmental impact assessment for offshore wind farms are reviewed in OSPAR 2006 and 2008 reports.

With regards to marine mammals, comprehensive monitoring was undertaken for target species (harbour porpoise and harbour seals) before, during and after construction of the Horns Rev wind farm in Denmark, culminating in seven years of data. Results from monitoring during the construction phase (summer 2002) showed a definite effect of construction activities on the distribution and behaviour of harbour porpoise. Harbour porpoises left the area when pile driving began, but returned a few hours after the end of each pile driving operation. Both data from acoustic and visual monitoring showed significant changes in porpoise behaviour up to 15 km from pile driving construction, in both the wind farm area and at reference sites. With regards to the seal monitoring, no clear evidence was found for a large-scale displacement of the seals from the wind farm area or the reef as a whole, during the months of construction. The study concluded there was no reason for serious concern about the loss of the wind farm area from the seal's normal habitat.

A good example of the potential ecological effects of OWF installation is provided by data from the Horns Rev OWF. Data gathered on the colonisation of foundations over two years, monitored the change to an epifauna-dominated assemblage, commonly associated with hard substrates. Concomitant with this is an estimated 60-fold increase in biomass in the OWF area compared with the infaunal biomass outside the OWF area, however, no assessment of the ecological significance of this change was made. A short term increase in biodiversity within the OWF area and faunal succession in the benthic community was shown but no assessment was made of how ongoing cleaning and maintenance may affect these conclusions in the medium to long term. Three species (the crustaceans *Jassa marmorata* and *Caprella mutica* and the midge *Telmatogeton japonicus*) were also recorded for the first time in Danish waters at the wind farm, with *Jassa marmorata* recorded in very high numbers (nearly one million individuals per metre squared). The newly available hard substrates have also provided new and more structurally complex habitats than those previously available, which now serve as nursery grounds for larger and more mobile species like the edible crab *Cancer parugus*. However, the changes described may not always be observed at all OWF sites, therefore it is impossible to make accurate generalisations or predictions about the effects of OWF construction on the benthic assemblage. This emphasises the need for targeted assessment and monitoring at OWF sites as deemed appropriate.

The second international case study reviewed was Nysted wind farm, also in Denmark. Results from harbour porpoise acoustic monitoring indicated a significant decrease in detection of porpoise clicks during construction compared to data gathered during the pre-exposure base-line period. At Nysted, the porpoises left the area during construction and also left the reference area 10 km away. After two years of monitoring during wind farm operation there remains a lower level of porpoise activity in the wind farm area while levels in the reference area have returned to baseline levels.

Both grey and harbour seals were monitored at Nysted. There were no indications that construction activities from late June 2002 to December 2003 and during the first two

years of operation in 2004-2005 affected the local Rødsand harbour and grey seal populations differently from the other populations in the western Baltic Sea. One notable observation, however, was that there was a reduction in the number of seals hauled out during pile driving.

The monitoring programmes at both wind farms were designed to examine whether numbers or behaviour of marine mammals changed during the course of wind farm development. However, while these surveys are very useful at showing an effect, it is still not clear what specific aspect of the construction phase caused the effect i.e. noise, increased boat traffic, changes in prey availability. In addition, the reference areas should have been far enough away that they were not impacted by development. Due to the differences in effects of construction activity on porpoises in these two locations, it can be concluded that the same species could react differently to the construction of wind farms in different areas.

10. Conclusions and General Recommendations

In addition to the issue-specific recommendations included in this report several overarching issues have emerged:

As a general conclusion, whilst the wording of licence conditions has evolved to reflect advances in our knowledge and understanding, both in terms of the science and engineering, in essence the intent of the various monitoring parameters has remained consistent. Due to delays in publishing reports or the lack of strategic reviews such as ME1117 where such changes have been reflected in new licences they have not to date consistently been retrospectively applied to extant FEPA licences.

Recommendation: The Licensing Authorities to review the outputs of ME1117 and, based on the lessons learnt, make the necessary amendments to FEPA licence conditions to provide clearer objectives (NB. This can be aligned with the ongoing review of FEPA licence conditions for offshore wind farms).

ME1117 has only been able to provide a snapshot based on data from a relatively small number of sites and time-series.

Recommendation: Future reviews should be undertaken as new sites are constructed and new data becomes available.

To date traditional approaches to monitoring have been applied to offshore wind farm developments. However, given the novelty of some of the issues, the scale of the developments and the drive to meet UK renewable energy targets new approaches should be considered to allow for optimal performance and benefit of monitoring strategies. The ME1117 reports suggest that these could include developing techniques to:

- monitor near-field effects on benthos;
- effects on fish populations relative to pressures from other factors;
- transboundary issues on migratory bird species;
- joint monitoring programmes between several sites and longer time-series for monitoring programmes (which should be possible under the Marine and Coastal Access Act where secondary legislation is likely to result in licences issued for the lifetime of the project).

The Licensing Authorities will need to determine whether these issues need to be addressed as licensing conditions, specific research projects or a combination of the two. Whilst such approaches may mean that the monitoring burden for some parameters increases, a more targeted approach may mean that these burdens can be better spread across the developments with specific sites being targeted to address specific issues, with other sites targetting others. Such approaches would need the full support and co-operation of industry.

Recommendation: The Licensing Authority, the Statutory Nature Conservation Agencies and Cefas to work together with other relevant organisations to consider novel approaches to monitoring of offshore wind farms and the most appropriate mechanism to take this recommendation forward. Industry (and the Crown Estate) input should be sought once the basic mechanisms are established. A feasibility study would be required to ensure that any approaches are achievable and scientifically robust.

For a number of the monitoring reports reviewed, it was not apparent what the developers were aiming to achieve by undertaking the work. The specifications for the works often expanded on the wording in the licence condition with no clear project rationale or establishment of hypotheses. In some cases it was also not clear how the conclusions were supported by the data. Greater thought is necessary to ensure that the parameters monitored, the techniques employed and the conclusions drawn are appropriate to the hypothesis being tested (rather than the monitoring being just a data gathering exercise) and are of a sufficient scale to account for natural change.

Recommendation: Rather than just describing what should be monitored, licence conditions should be expanded to explain the underlying rationale, which should provide the basis for developing hypotheses. Consideration should be given to better ways of presenting reports with clearly defined hypotheses and the steps taken to test these to meet licence conditions. Clear links between those hypotheses and the conclusions and uncertainties highlighted during the EIA process should also be made.

The need and extent of power analyses should be proportionate to the issue under investigation, but monitoring should include the rationale for the approach taken and the methods used to explain natural variability.

Recommendation: Greater consideration should be given to the implications of natural variability.

It has been difficult to get an overview of which monitoring conditions were due when and if/how they have been agreed with the Licensing Authority. Also, in some cases pre-construction baseline reports have been submitted after construction has commenced or with little time for their content to be reviewed prior to construction, so any data gaps or errors cannot be remedied and as such the monitoring objectives could be flawed.

Recommendation: Checklists and/or programmes should be developed listing the conditions, scheduling when reports need to be submitted, showing which conditions have been met, which have been amended, when any specifications or alterations were agreed by the Licensing Authority or if any requests to amend conditions have been declined.

11. Summary of Key Findings and Conclusions

Actions for:	Developers	Regulators, Advisors and Statutory Consultees
General:		
1.	When designing monitoring programmes developers must devise detailed rationales and identify the impact hypotheses to be tested, i.e. what is being monitored and why; which parameters will interact and why	Clearer definitions on what monitoring is requested and why
2.	Monitoring reports should follow a common format to detail what monitoring work was undertaken, why it was undertaken, and how the licence conditions have been met, i.e. the reports must pose and provide answers to questions.	
3.	<p>Developers need to comprehend the link between the predictions on effects identified in the Environmental Statement for their project and the monitoring licence conditions. The rationale must therefore:</p> <ul style="list-style-type: none"> - Describe the prediction made in the Environmental Statement - Describe how this defined the FEPA licence condition (and the impact hypotheses to be tested) - What baseline data is required (and why) - The type, duration, frequency, spatial extent and analyses adopted for the during/post-construction monitoring 	Making wording of licence conditions more explicit and take appropriate enforcement.
4.		ME1117 is an initial review of a limited time series – future reviews are required as the dataset increases
5.	Monitoring activities and reports need must acknowledge and assess interactions between sediments – benthos – fish – birds – mammals – noise, e.g. can observations of fish distribution explain changes in bird feeding behaviour	Making wording of licence conditions more explicit and taking appropriate enforcement action where such interactions are not assessed.
6.	In all monitoring activities consistency between repeat surveys is crucial for cause and effect relationships to be investigated. This is particularly important if different consultants are used for the repeat surveys, a methodology should be agreed at the outset and followed throughout (unless techniques are proven inadequate at which point a reviewed strategy needs to be agreed with the Licensing Authority)	
7.	Monitoring programmes must have adequate temporal and spatial scales to test the hypotheses set-up under point 1. This includes realistic considerations of other wind farm sites and activities that can interact with the site being investigated.	Making wording of licence conditions more explicit and take appropriate enforcement.
8.	Not detecting an impact is not the same as there being no impact, only that there may	

	have been inadequate statistical power to detect any effect. Care should be taken not to draw false conclusions from monitoring data. Developing testable hypotheses (Point 1) should reduce such risks.	
9.		As the knowledge base for the potential for wind farms to affect the marine environment is increasing all the time, licence conditions need to be reviewed at regular intervals to ensure that they reflect current understanding and consideration given to the need for future research and mitigation measures.
10.	The Guidelines for the conduct of benthic studies at aggregate sites (Boyd 2002) are currently being reviewed (due for publication in late 2010). This improves the available guidance for aspects of Benthos and Coastal Processes monitoring methodologies, and FEPA conditions should be reviewed once this is published to ensure continuity.	
<i>Benthos (including colonising epifauna):</i>		
11.	Benthic monitoring requires a minimum of three replicates per station and all replicate samples must be processed, analysed and reported.	
12.	One baseline survey is insufficient to determine temporal change, complementing this with national data-sets (e.g. the UK Marine Monitoring and Assessment Strategy (UKMMAS)) may aid understanding of natural variability. Incorporation of more regional based monitoring/assessment should be considered (including the Round 3 Zonal Assessments).	Three years post-construction monitoring is insufficient to identify change attributable to wind farm construction. Licence conditions should be amended to reduce the frequency of infaunal monitoring but over a longer period of time (e.g. post-construction plus one year, five years and ten years).
13.		Long-term effects of epifaunal colonisation are still unknown. The observed increases in biomass associated with those organisms colonising the sub-sea structures may have long-lasting and far-reaching effects on the surrounding benthos, and opportunities for the spread of invasive species (a Good Environmental Status Descriptor under the Marine Strategy Framework Directive) evaluated. Licence conditions requiring colonisation monitoring are therefore required (consideration should also be given to research projects).
14.	Statistical analyses within monitoring reports do not always appear to be consistent or correct and can raise questions on the validity of conclusions. Any incorrect analysis compromises in-site, cross-site or cross-study comparisons. It is therefore imperative that adequately qualified and experienced analysts conduct data analysis and interpretation to ensure that suitable statistical analyses are undertaken.	
15.	QA/QC procedures should be employed on all data analysis and evidence supplied with the monitoring reports.	
<i>Fish:</i>		
16.	Monitoring studies should make better	

	integration with national data of trends in fish species. This may assist in assessing and monitoring wind farm impacts and aid comparison of effects.	
17.	EIA and monitoring reports focus on species of conservation or commercial importance, but the ecological importance of other species, e.g. as prey is a notable omission.	
18.	A more targeted approach to monitoring is required, including monitoring over several sites to provide better spatial coverage, greater consideration of the consequences of temporal variability and assessment of cause and effect relationships. Longer time series and or greater spatial extents for surveys may be required. Developers should co-operate on data collection to facilitate this greater coverage.	Making wording of licence conditions more explicit, improve guidance.
19.	Spawning ground surveys and noise propagation modelling should be conducted in line with current best practice if developers want the regulators to consider amendments to any timing restrictions.	The requirements on spawning ground surveys should be applied as standard in areas where restrictions on construction activities are included within the FEPA licence conditions.
20.	In some cases inappropriate gears have been used, e.g. beam trawls inappropriately used to survey pelagic species. This leads to under representation of fish assemblages. It is essential that appropriate gear types are used (survey rationales and impact hypotheses should ensure appropriate gears are chosen).	
Coastal Processes:		
21.	Suspended sediment concentration (SSC) monitoring has upheld predictions made in the Environmental Statements that impacts are both short-term and localised (for monopiles and cable installation only). SSC is still an issue for other foundation types and where sensitive receptors are present.	The need for SSC monitoring for monopile foundations and cable laying should be determined on a site-by-site basis (i.e. no longer applied as a standard monitoring condition)
22.		Effects of scour wakes, as a result of secondary scouring requires further investigation
23.		Monitoring of waves for diffraction/interference effects of monopile structures is not required.
24.	Multibeam surveys should be the preferred methodology to measure change from scouring and cable laying	
25.	On site disposal of drill arisings (especially chalk) could be an issue at some sites. Release of chalk arisings in a low energy (and hence low suspended sediment) environment may have wider impacts to marine organisms.	Improved assessment in the environmental impact assessment and site-specific licence conditions should be developed.
26.	Impacts on seabed morphology from construction activities (e.g. jack-up legs) needs better coverage in environmental impact assessment (and where	

	appropriate monitoring).	
Noise:		
27.	For construction noise: a) Sound generated during pile-driving is significantly higher than ambient b) Propagation of this sound is variable Dedicated monitoring during construction should therefore continue at all sites.	
28.		Licence conditions for operational noise can be amended to require only one year post construction (reduced from the current requirement for 3 years), unless site-specific issues merit a longer time-series.
29.	An increased level of assessment of noise impacts on fish, particularly from pile-driving activities is required at the environmental impact assessment phase of the project, including better understanding of noise propagation (and the site-specific influences of sediment type, water depth and bathymetry) and temporal/spatial extent of spawning grounds. This may include increased levels of modelling and surveying.	Scoping advice to ensure that these issues are adequately assessed at the earliest opportunity, i.e. ensure that this issue tackled pre-application (rather than post-application as is currently the case).
30.		The content and quality of noise baseline surveys has been variable. Development of standard methodologies and more stringent enforcement is required to ensure that baseline surveys are adequate.
31.		Monitoring to date suggests that noise from construction activities are potentially the most harmful to marine life. A strengthening of monitoring conditions during construction is advisable.
32.		A new licence condition should be included requiring all noise monitoring data to be assessed in terms of the local environment, e.g. sediment type, water depth, bathymetry.
33.	It was often difficult to determine what measurements were taken from what locations, charts showing precise locations of measurement with the wind farm areas, interest features (e.g. spawning grounds, haul-out areas), water depth, bathymetry and scale must be included in all reports.	
34.	Metadata tables should be included in all reports (see Table 1).	
Birds:		
35.	Standardised monitoring techniques for boat-based and aerial transects are in place, however, further techniques (e.g. motion sensitive still/video cameras, infrared cameras, thermal imaging, X-band radar) require assessment and development to investigate barrier effects or collision risk.	Making wording of licence conditions more explicit.
36.	Evidence is insufficient for barrier effect and collision risk/rate monitoring to be removed. Because monitoring techniques require further development it is impossible to conclude that the limited effects recorded to date, are not a consequence of low statistical power.	

37.		Production of standardised methodologies are required for monitoring of effects on migration, SNH (2009) may be a useful starting point.
38.	Many reports contain large volumes of almost raw data, anecdotal observations and short textural summaries. More detailed analyses and reporting of this data would make these reports more accessible and usable to the regulators.	
39.	Repeating the same information but with different emphasis is a drawback in some reports. All conclusions must be evidence based and it is not appropriate for information to be stretched to make a point (if there is insufficient information the point should not be made).	
Marine Mammals:		
40.	Site-specific Marine Mammal Monitoring Protocols should be developed and implemented for all offshore wind farm developments, to ensure that marine mammal monitoring is better defined and targeted.	Standard licence condition(s) should be developed.
41.	Use of trained and dedicated Marine Mammal Observers and concurrent use of Passive Acoustic Monitoring (PAM) is recommended. Specific mitigation measures need to be developed and implemented for poor weather conditions when observation and PAM are limited (see JNCC 2009).	
42.		The minimum 500m exclusion zones described in JNCC (2009) should be described in the FEPA licence conditions.
43.		Standardised methodologies for recording animal sightings, group size, behaviour etc should be developed to allow comparison across different sites.
44.	Greater importance should be given to pre-construction/baseline data as this is the reference data for any post-construction monitoring, improved surveys rationales and impact hypotheses (i.e. to monitor 'change') should help in this regard. Knowledge of habitat use is an essential part of baseline monitoring to determine importance of the area to specific species.	Making wording of licence conditions more explicit.

12. References

- Boyd S.E. (compiler) (2002). Guidelines for the conduct of benthic studies at aggregate extraction sites. London: Department for Transport, Local Government and the Regions.
- Cefas (2005). Assessment of the Significance of Changes to the Inshore Wave Regime as a consequence of an Offshore Wind Array. Defra Project Code A1227.
- Cooper, B., Rees, J. and Coates, T. (2008). Review of Round 1 sediment process monitoring data – lessons learnt. A report for the Research Advisory Group on behalf of DECC.
- Gill, A.B. (2005). Offshore renewable energy: ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology*, 42: 605-615.
- JNCC (2009). Statutory nature conservation agency protocol for minimising the risk of disturbance and injury to marine mammals from piling noise.
- Maclean, I.M.D, Skov, H. and Rehfisch, M.M. (2007) Further use of aerial surveys to detect bird displacement by offshore windfarms, October 2007. COWRIE.
- OSPAR (2006). Review of the current State of Knowledge of the Environmental Impacts of the Location, Operation and Removal/Disposal of Offshore Wind Farms. Status Report April 2006. Biodiversity Series.
- OSPAR (2008). Assessment of the Environmental Impact of Offshore Wind Farms. Biodiversity Series.
- RPS Energy (2008). Marine mammal observer's and passive acoustic monitoring operator's report during Lynn and Inner Dowsing offshore wind farm installation.
- SNH (2009) Guidance on Methods for Monitoring Bird Populations at Onshore Wind Farms (<http://www.snh.gov.uk/docs/C205417.pdf>)