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

Benthic Ecology

Contract ME1117

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1. Executive Summary

All offshore wind farm (OWF) developments within the UK require a FEPA licence. To this licence, a number of conditions can be applied to ensure that environmental parameters determined as meriting observation during the application assessment are monitored. Specifically, concerns about the effects of OWFs on the benthic environment have been expressed and therefore require monitoring.

This report considers the licence conditions and benthic monitoring data for OWFs during and after their installation. Standard licence conditions and survey techniques are highlighted for operational OWFs and for those under construction, namely North Hoyle OWF, Barrow OWF, Kentish Flats OWF, Scroby Sands OWF and Burbo Bank OWF.

The monitoring surveys undertaken so far have provided a valuable insight into the immediate impacts of Round 1 wind farm construction and operation. The monitoring shows that no detrimental effects have been detected so far. However, detecting the extent of natural variability and the ability to draw conclusions from a short time-scale of three years post-construction data is limited. The monitoring reports also demonstrate that there is a need to tailor monitoring programmes specifically to the impacts predicted in the EIA, with monitoring objectives clearly stated at all stages, as this has not always been the case. The concept that monitoring surveys should not be perceived as a standardised 'one survey fits all approach' is emphasised.

The quality of statistical analyses across monitoring studies is variable, which restricts the effectiveness of cross-site reviews. There is no single correct way of analysing data, however the use and reporting of QA/QC procedures would ensure that all datasets and results over space and time are compatible.

Epifaunal colonisation of monopiles can result in a localised increase in species diversity, whether this is a 'beneficial' impact as is often predicted, is debatable and highly subjective as the colonising species are different from the original community. However, it is worth noting that the species observed colonising monopiles are the same as those on other rocky substrates. The long-term effects of these changes are still unknown.

To address the limitations in obtaining detailed temporal baseline data and an understanding of natural variability, studies should collaborate with national monitoring programmes (such as National Marine Monitoring Programme - NMMP). Also, the potential of following the model set up by the aggregate industry to address regional issues should be considered (i.e., REAs), where the use of such a tool, independently or in collaboration, could be highly beneficial to the offshore wind farm industry in the future.

Longer term datasets are required to ascertain the long-term effects of OWF installation. The application of regional methods to address the highlighted limitations in existing monitoring strategies can allow site-specific monitoring to be considered in terms of the frequency of post-construction infaunal monitoring. In terms of infaunal monitoring, less frequent surveys over a longer period of time are recommended, with more frequent monitoring concentrating on the known 'near-field' and colonisation impacts.

2. Introduction

The main purpose of FEPA licence conditions relating to benthos is to offer the benthic environment protection from impacts associated with offshore wind farm (OWF) construction activities. Licence conditions require monitoring to generate information that will help to validate predictions made in site-specific Environmental Statements, and to determine change in species distribution, abundance and community structure that may be attributable to the installation of the windfarm. The regulators use the outputs from the licence conditions (including monitoring) to inform the need and scope of revisions to ongoing and future monitoring and mitigation requirements to ensure that impacts are suitably managed.

This report considers the licence conditions and monitoring relating to benthos for OWFs with available post-construction data. These OWFs are: North Hoyle; Barrow; Kentish Flats; Scroby Sands and Burbo Bank. It draws conclusions from this reviewing exercise and provides recommendations for future monitoring in terms of five key issues:

1. What has been learned about the effects of offshore wind farms on benthos?

2. What has been learned about the adequacy of monitoring and analytical approaches for benthos?

3. Recommendations on whether any conditions can be removed (because we now have sufficient information).

4. Recommendations on whether any new conditions or approaches to monitoring/analysis should be adopted.

5. Recommendation on the need and scope for comparability in datasets and reporting styles.

3. Potential Impacts of Wind Farm Development on Benthic Organisms

Since the construction of large offshore wind farms was initiated, concerns about their effects on the benthic environment have been expressed.

The benthos includes all organisms that live upon or within the substrate at the bottom of the sea. They can be subdivided in terms of which part of the habitat they inhabit and by the taxonomic composition and size of the organisms defined. For example, infauna are animals of any size that live within the sediments, whereas epifauna are animals that live on or in close association with the bottom, either attached to a hard surface (on rocks or pilings) or move on the surface of the sediment. Similarly, macrobenthos are organisms (animal or other) retained on a 1 mm mesh size sieve. It is commonly the macro-infauna (benthic animals larger than 1 mm) and epifauna that are used in benthic monitoring. They include mostly invertebrates, like worms and molluscs, and the bottom dwelling vertebrates (e.g., flat fish) that prey upon them.

Impacts directly associated with OWF construction can be assigned to five different categories, namely, noise and vibration, temperature, electromagnetic fields, contaminants and disturbance. These are reviewed further within the OSPAR Commission Review of the Current State of Knowledge on the Environmental Impacts of the Location, Operation and Removal/Disposal of Offshore Wind-Farms (2006). In addition to direct impacts during OWF construction and operation, the potential long term effects on the benthic environment must also be considered. Concerns are focused mainly on whether and how the benthic habitats in the vicinity of the OWFs are affected by changes in the hydrodynamic regime, and whether the effects of the installations, which act as artificial settling substrates for sessile organisms,

are properly assessed. The ecological effects of OWFs include increased habitat structure and heterogeneity, changes in hydrodynamic conditions and modified sediment transport patterns. The ecological response of the benthos could involve long-term changes in organism abundance, biomass, species diversity, community structure and functional properties such as nutrient cycling or bio-turbation (see reviews by Zucco et al (2006) and Linely et al (2007)).

A good example of the potential ecological effects of OWF installation is provided by data from Horns Rev OWF (Leonhard and Pedersen 2004). Data gathered on the colonisation of foundations over two years monitoring an epifauna-dominated assemblage commonly associated with hard substrates. Concomitant with this is an estimated 60-fold increase in infaunal 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. 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*.

The changes described above may not be observed at all OWF sites, for example, the biodiversity may differ between sites. Therefore, whilst the results may be indicative, it is impossible to make accurate predictions about the effects of OWF construction on the benthic assemblage. This emphasises the need for continued assessment and monitoring at every OWF site.

During OWF construction, practices such as dredging and blasting may adversely affect the local benthic populations and therefore have an indirect effect on other populations that feed on them. These effects, however, are likely to be short-lived.

The presence of an OWF site will also modify the behaviour of fishermen within the area, whether this will be an exclusion of trawler activity within a site, or alternatively, a more intensive linear trawling pattern between turbines, is unknown, but may have additional impacts to the benthic community. An additional point is that fishing activity may be displaced to reference sites, thus potentially masking any deleterious impacts within the wind farm area as they are negated by such changes in fishing effort. Changing fishing patterns could therefore be a target for monitoring in the future.

4. Licence Conditions

All OWF developments within the UK require a conditional FEPA licence to ensure that those environmental parameters determined as meriting further observation within the application assessment are monitored. The main purpose of the FEPA monitoring conditions is to provide reassurance that the predictions on environmental impacts identified by the Environmental Statements are verified. As a standard, monitoring includes a pre-construction survey to provide a baseline for subsequent monitoring, another survey during construction, and three more annual surveys on consecutive years following construction.

Further supplementary conditions may be implemented within the FEPA licence to specify additional, case-specific requirements for benthic monitoring, and are included in an Annex to the FEPA licence. Variations in the specific wording of licence conditions occur following modification of standard licence conditions over time, and serve to address site-specific issues (see Table 1).

Table 1. Comparison of Standard Licence conditions

Wind Farm	1. Sample locations for ongoing monitoring	2. Sample number and replicates	3. Colonisation of monopiles	4. Inter-tidal sampling	5. Sediment and benthic data sets must be closely related	6. Additional site specific conditions
Operational						
North Hoyle	Y	Y (specific)	Y	Y	Y	
Burbo	Y		Y	Y	Y (variation)	
Barrow	Y	Y (specific)	Y	Y	Y	
Scroby						Y
Kentish Flats	Y	Y (specific)	Y	Y	Y (variation)	
Under Construction						
Rhyl Flats	Y	Y (specific)	Y	Y	Y	
Lynn	Y		Y (variation)	Y	Y	Y
Inner Dowsing	Y		Y	Y	Y	Y
Gunfleet	Y		Y (variation)	Y	Y	

1. Sample locations for ongoing monitoring: “Sample locations for ongoing monitoring must be determined by factors such as precise foundation locations, location of cables. Sample locations must also take full account of factors such as coastal process modelling outputs (for sediment transport / deposition information) and geophysical surveys (to ensure adequate coverage of sea bed habitats)”

2. Sample number and replicates: “Sampling should involve a minimum of 3 replicates at each station and the number and location of stations should be determined making use of the data used to characterize the site as part of the Environmental Statement. This monitoring should include a suitable baseline dataset and make adequate use of control sites.”

3. Colonisation of monopiles: “Colonisation of monopiles and scour protection must be determined by diver-operated video observations and analysis with some accompanying sample collection for verification and identification.”

4. Inter-tidal sampling: “Intertidal invertebrate sampling must be undertaken at lower, mid and upper shore sampling stations along three transects running perpendicular to the shore in the area of the cable landfall.”

5. Sediment and benthic data sets must be closely related: “NB. The sedimentary and benthic data sets must be closely related.”

4.1. Case-specific Licence Variations

4.1.1. North Hoyle

The licence condition regarding the number of samples and replicates to be taken provided specific detail on the number and distribution of sampling locations within the wind farm area, along the cable route, etc. Specification was only provided following the receipt of a detailed monitoring plan prior to consent.

4.1.2. Burbo

No specific licence conditions were included regarding sample numbers or replicates, as reference was made to the published DTLR Benthic Guidelines (Boyd et al 2002)). Reference to the DTLR Benthic Guidelines (Boyd et al 2002) becomes more common in future licences, and is included in Lynn, Inner Dowsing and Gunfleet.

The specific licence condition referring to investigating the correlation between sediment and faunal datasets was an amendment to an existing generic condition that has been modified over time.

4.1.3. Barrow

The licence condition regarding the number of sampling locations and replicates to be taken provided specific detail on the number and distribution of sample locations within the wind farm area, along the cable route, etc.

4.1.4. Scroby Sands

As the first wind farm to be consented, the licence conditions at this site differed to those used subsequently. A general condition was specified in the licence, with full detail of the monitoring regime, survey techniques, analytical techniques, sample number and their location incorporated within an Annex.

4.1.5. Kentish Flats

The licence condition regarding the number of sampling locations and replicates to be taken provided specific detail on the number and distribution of sample locations within the wind farm area, along the cable route, etc.

The requirement to carry out colonisation of monopiles and scour protection has been slightly modified to refer to appropriate video observations, rather than to diver-operated video operations.

4.1.6. Rhyl Flats

The licence condition regarding the number of sampling locations and replicates to be taken provided specific detail on the minimum sample number and indicative sample locations, within the wind farm, along the cable route, etc.

4.1.7. Lynn

Standard licence conditions were used, including reference to the DTLR Benthic Guidelines (Boyd et al 2002). A site specific condition was added to ensure appropriate techniques to identify and monitor the presence of *Sabellaria* reefs.

The requirement to carry out colonisation of monopiles and scour protection has been slightly modified to with the inclusion of drop down video analysis as well diver-operated video operations.

4.1.8. Inner Dowsing

Standard licence conditions were used, including reference to the DTLR Benthic Guidelines (Boyd et al 2002). A site specific condition was added to ensure appropriate techniques to identify and monitor the presence of *Sabellaria* reefs.

The requirement to carry out inter-tidal sampling was dependent on whether directional drilling was not used.

4.1.9. Gunfleet

Standard licence conditions were used, including reference to the DTLR Benthic Guidelines (Boyd et al 2002). The requirement to carry out inter-tidal sampling was dependent on whether directional drilling was not used.

The requirement to carry out colonisation of monopiles and scour protection has been slightly modified to refer to Remote Operated Video observations, rather than to diver-operated video operations.

5. Survey Techniques

Standard survey techniques are not always specified within the terms of the FEPA licence conditions; instead these can vary between sites and may be tailored to address site-specific conditions (Table 2). There are, however, guidelines in place to assist with the identification of the best survey techniques to use under different conditions to optimise the acquisition of high quality data (i.e.,, DTLR Benthic Guidelines (Boyd et al 2002)). Further studies such as the COWRIE best practice study of documentation and dissemination of marine biological data (2007), and the Marine Renewable Energy Research Advisory Group funded study 'Statistical Basis for Seabed Benthic Monitoring as a Tool for Environmental Management in the Offshore Windfarm Industry (Unpublished)', may also feed into best practice approaches for surveying and reporting into the future.

Table 2. Summary of survey techniques specified for each FEPA licence application.

Wind Farm	Survey	Year	Acoustic Survey	Photo/Video	Infauna	Epifauna	Sampling Gear	PSA	Chemistry	Data Type
North Hoyle	Characterisation	2001								
	Pre-construction	2002	N	N	Y	N	Day Grab	Y	Y	Quantitative
	Construction	2003	N	Y	Y	Y	Day Grab Beam Trawl Other	N	N	Quantitative/ Semi- quantitative
	Post-construction	2004-2006	Y	N	Y	Y	Day Grab Beam Trawl	Y	Y	Quantitative
Burbo	Characterisation	2002	Y	N	Y	Y	Day Grab Beam Trawl Other	Y	Y	Quantitative
	Pre-construction	2005	N	Y	Y	Y	Day Grab Beam Trawl	Y	Y	Quantitative
	Construction	2006	N	Y	Y	Y	Day Grab Beam Trawl Other	Y	Y	Quantitative
	Post-construction	2006-2007	Y	Y	Y	Y	Day Grab Beam Trawl Other	Y	Y	Quantitative
Barrow	Characterisation	2002	N	Y	Y	Y	Day Grab Beam Trawl	Y	Y	Quantitative
	Pre-construction	2005	Y	N	Y	Y	Day Grab Beam Trawl Other	Y	Y	Quantitative
	Construction	2006	N	Y	N	N	N/A	N	N	Qualitative
	Post-construction	2007-2008	Y	Y	Y	N	Day Grab Other	Y	Y	Quantitative/ Semi- quantitative

Wind Farm	Survey	Year	Acoustic Survey	Photo/Video	Infauna	Epifauna	Sampling Gear	PSA	Chemistry	Data Type
Scroby Sands	Characterisation	1999	N	N	Y	Y	Day Grab Dredge Beam Trawl	Y	N	Semi-quantitative
	Pre-construction									
	Construction									
	Post-construction	2005	Y	N	Y	Y	Hamon Grab Beam Trawl	Y	N	Quantitative
Kentish Flats	Characterisation	2002	Y	Y	Y	Y	Hamon Grab Beam Trawl Oyster dredge Other	Y	N	Quantitative
	Pre-construction									
	Construction									
	Post-construction	2005-2007	Y	N	Y	Y	Hamon Grab Beam Trawl	Y	N	Quantitative

6. UK Wind Farm Case Studies

6.1. North Hoyle

North Hoyle offshore wind farm is located approximately 6km off the coast of North Wales at Prestatyn. The wind farm features 30 2MW turbines; ancillary equipment offshore includes two meteorological masts. Inter-array cabling connects the turbines and two export cables connect the wind farm to an onshore sub-station at Rhyl. Offshore construction commenced in 2003 and was completed during 2004.

6.1.1. Predicted Impacts

Minor and localised impacts were predicted, due to physical impact of construction (pile driving, jack-up barges). A loss of 0.02km^2 of seabed habitat directly below piles and scour protection was predicted. The faunal assemblage was characterised as being representative of that which is widespread and common throughout Liverpool Bay. Recovery of benthic communities was predicted to be rapid.

6.1.2. Licence Conditions

Monitoring during pre-construction, operational, and post-construction phases was specified within the licence. Standard licence conditions specifying the factors to be taken into account when determining the location of monitoring stations, and the sample number and location were also specified within the licence. Conditions regarding the assessment of colonisation of turbine monopiles, and inter-tidal surveys if the cable route ran along the River Clwyd were also included.

6.1.3. Survey Techniques

Sub-tidal. Pre-construction monitoring of infauna was carried out using a Day grab at 17 sampling sites. Following consultation, an additional three sites were added within the turbine array area, thereby totalling 20 sites for monitoring during and post-construction. Monitoring of epifauna was carried out using 2m beam trawls at 22 stations. The data collected during the characterisation survey in 2001 were deemed to be suitable as a baseline and the same sites were re-sampled during and post-construction. An investigation of the rate and extent of epifaunal colonisation of turbine monopiles was carried out in 2004 and again in 2008.

Inter-tidal. As the cable route was subsequently amended to avoid the River Clwyd, the licence requirement to carry out inter-tidal monitoring was no longer necessary.

6.1.4. Results

Sub-tidal. The studies concluded that there was a great deal of variation in the numbers of individuals and of species both within and outside of the wind farm area, with no obvious link to changes brought about by the development. However, multivariate analyses of infaunal communities did suggest that changes in community composition had occurred within the OWF and along the cable route during construction and into the year immediately following construction. The marine biotopes identified from data obtained during the 2006 survey are not considered to be significantly different to those biotopes identified prior to development in 2001. Epifaunal studies showed that the abundance of epifaunal organisms varied considerably over the years, but with no discernible trends in relation to the OWF construction. The number of epifaunal species varied little over the years.

6.1.5. Reviewer's comments

Sub-tidal. Although considerable analyses have been performed on the data, there is a lack of results from standard univariate diversity analyses, as well as of statistical backing of many statements, which detracts from the confidence and authority that can be ascribed to the conclusions presented. Previous concerns, such as the potentially detrimental effects of noise, vibration or disturbance on the resident fauna appear to have been dealt with and shown to be little consequence (limitations of data analysis aside). Given the acute lack of real data with which to test these concerns, this study has nonetheless made a valuable contribution to the understanding of such issues.

In terms of new issues, the survey design of the present study did not allow for the accurate testing of the effects of scour around the monopiles on the benthic assemblage. The logistical constraints of many sampling techniques limit the ability to test these small scale effects, and therefore to test the predictions made during the initial EIA. For example, predictions were made that there would be impacts to the benthic community within 30m of the monopiles due localised scour effects. However, samples could only be taken within 50m of the turbine due to safety restrictions.

6.2. Burbo

Burbo OWF is located approximately 6km from the coastlines of Wirral and Liverpool. The wind farm features 25 3.6MW turbines. Construction commenced in 2006 and continued until 2008, when the last of the scour protection measures were emplaced.

6.2.1. Predicted Impacts

The EIA predicted a loss of seabed habitat due to installation and scour protection of 0.02km^2 (0.2%) of the wind farm area. Statutory protected benthic species were not anticipated in the area. Faunal communities are thought to be typical of those present in the Liverpool Bay area.

6.2.2. Licence Conditions

Standard monitoring periods were specified within the licence. Slight amendments to standard conditions were made (Table 1), but no additional site specific conditions included. No specific licence conditions were included regarding the number of samples or replicates necessary but applicant was referred to published guidelines on the conduct of benthic surveys. Evidence of quality assurance measures, detailed statistical analyses and species lists were requested.

6.2.3. Survey Techniques

Sub-tidal. Sampling of infauna was carried using a Day grab at 20 stations. At 12 of those 20 stations, 2m beam trawl sampling was undertaken to provide information on epibenthic invertebrate communities and smaller demersal fish. Post-construction monitoring under the terms of the FEPA licence is still ongoing.

Inter-tidal. A number of surveys have been undertaken to monitor the effect of cable installation works across the intertidal area. Sampling methods were adapted to address concerns regarding the effect of cable trenching on the inter-tidal invertebrates, given their importance locally as a food source for birds. A baseline biotope survey was conducted shortly before works were due to begin, supported by sediment core samples. This was followed by a photographic survey immediately after the works to record physical recovery of beach sediments along the route and repeat sediment core sampling after final cable landfall

works. Finally, a repeat biotope survey was undertaken, as a detectable impact identified by repeat sediment core sampling required further study to verify the conclusions on the effect of the cable installation works.

6.2.4. Results

Sub-tidal. Much temporal variability in infaunal abundance and species richness was observed. This was consistent with natural variability within the area. There were no great concerns over the reported changes of biotope type that occurred at specific sampling stations as these were consistent with documented 'switching' between different variants of a more generalised community type. There were, however, concerns around a notable trend in the reduction of the bivalve *Spisula* over the whole site in the period 2005-2007.

Inter-tidal. The repeat biotope survey results were generally very similar before and after cable burial works, and comparable to those reported in the Environmental Statement. Overall the monitoring showed small changes in beach infauna, but no significant detrimental effect on inter-tidal invertebrate communities or sediments.

6.2.5. Reviewer's comments

Since the monitoring programme is not yet completed, it is unknown whether there has been any lasting effect of the construction on the benthic community. Care should be taken when stating that inter-annual differences can be attributed to natural variation (implying no construction effect); it might be more acceptable to conclude that the observed variability is considered to lie within the limits of natural (normal) variability. It is recommended that summaries should also clearly state that a 'construction effect' cannot be ruled out at this stage, but there is clearly not evidence of a 'detrimental construction effect' at this site. This also highlights the importance of understanding the magnitude of natural variability in being able to adequately assess the significance of any effect attributable to the wind farm. This is also important in terms of seasonal variability, where it would be useful to have some finer-scale temporal monitoring to enable an assessment of seasonal variability. Biological 'seasons' can 'drift' to some extent, and more information is needed to be able to discriminate year-on-year changes from short term seasonal changes (and hence test the hypothesis that the OWF has had no effect).

There are no significant concerns with respect to the reported changes of biotope type that have occurred at specific sampling stations as these are consistent with documented 'switching' between different variants of a more generalised community type. With the exception of change to habitat resulting from the introduction of foreign substrates (monopiles and scour protection), where it is indicated that the magnitude of change caused by natural variability is likely to be greater than any affect directly attributable to OWF construction, this needs to be monitored over time scales appropriate to its potential effect (i.e., over decades rather than months/years). Whilst this may fall beyond the scope of conditions that can be appended to FEPA licences, this is something that needs to be addressed either through collaborations within the industry or through R&D studies.

The importance of carrying out surveys to monitor the colonisation of monopiles is also highlighted in this case. The need for these surveys is to establish what happens on and immediately around the turbine installation, and which new species are exploiting the hard substrates (metal & rock) introduced by the construction. Such studies conducted at every OWF site (round 1,2 & 3) will provide information over a broad scale spatial network of sites that will be useful in assessing the potential benefits or dangers of the 'artificial reefs' (e.g. enhanced biodiversity hotspots, refuges for juvenile fish, but also 'stepping stones' for invasive species'). This information will also be valuable at the end of the OWF life-span,

informing decisions on the most appropriate strategy for decommissioning (e.g. 'remove & restore' vs. 'leave in place').

6.3. Barrow

Barrow OWF is located in the eastern Irish Sea near Barrow-in-Furness. It features 30 3MW turbines, and the transmission cable runs into Morecambe Bay where it is connected to the National Grid in Heysham. Its construction took place between March 2005 and July 2006, and became operational in July 2006.

6.3.1. Predicted Impacts

The EIA predicted a loss of seabed habitat due to turbine installation and scour protection of approximately 3.38km^2 of the wind farm area (0.026%). Statutorily protected benthic species were not anticipated in the area. Most of the sampling sites within the wind farm area contained muddy sand with some gravel, supporting a diverse *Amphiura*-dominated community typical of the area.

The EIA also stated that "the presence of monopiles and any scour protection is predicted to be beneficial by providing a surface for encrusting organisms, potentially increasing biodiversity, while also providing shelter and food for fish and bird species."

6.3.2. Licence Conditions

Standard monitoring periods were specified within the licence (Table 1). The applicant was referred to existing guidelines on the conduct of benthic surveys for recommendations on the number and location of sampling sites.

6.3.3. Survey Techniques

Sub-tidal. Sampling of infauna was carried out using a Day grab at 25 stations. Sample locations were chosen to represent different habitat and sediment types, potential areas of sediment deposition, and four sites to specifically investigate near field effects (<6 m from monopile within predicted extent of scour). Epifauna were sampled using a 2m beam trawl at seven stations, including two reference stations. Sampling was carried out in December, except for the first post-construction survey, which was carried out in March. Monitoring of epibenthic colonisation of monopiles was undertaken at six representative monopiles along a depth profile using a diver-operated video transect extending from the inter-tidal zone to the seabed.

Inter-tidal. Three transects were taken along and 50m to either side of the proposed cable route. Samples were taken from 9 locations, 3 sites at low, mid and upper shore. Due to two potential cable routes across the upper shore, two additional stations were sampled. Samples were collected using a 0.1m^2 quadrant and removing sediment to a depth of 15cm.

6.3.4. Results

Sub-tidal. The benthic assemblages within the wind farm area appear to have changed relative to those at the reference sites between pre- and post-construction surveys. The main difference in similarity was due to the high numbers of the brittle star *Ophiura*, present in the post-construction survey, and also the bristle worms *Nephtys* and *Amphiura* in the pre-construction survey. However, the results do not clearly differentiate between survey sites or discuss differences observed within and outside of the OWF area. Reported results are attributed to the observed increase in sediment grain size. Epifaunal species colonising the turbine bases were representative of those found naturally in the region and had become

well established by 2008. No species of nature conservation interest or invasive/alien species were observed.

Inter-tidal. Higher numbers of species and individuals were observed in the post-construction surveys than in the pre-construction survey. The similarity between communities recorded in 2004 and 2007 is low, thought to be caused by the high abundance of some species in 2007.

6.3.5. Reviewer's comments

Whilst there is a change in the community composition between 2004 and 2007, the pattern of community structure across the whole site has not changed. This supports the view that the recorded changes are likely attributable to 'natural variability over time' than to a significant causal effect of the wind farm construction. The report supports evidence that their effects on benthic communities appears to be insignificant in comparison to the magnitude of change attributable to 'natural causes'. However, longer term data sets need to be acquired to establish that this continues to be the case over the projected life-time of the development.

6.4. Kentish Flats

The Kentish Flats OWF is situated outside the main shipping lanes of the Thames, 10km from the East Quay in Whitstable. Construction started in 2004 and was completed in 2005. It consists of 30 3MW turbines.

6.4.1. Predicted impacts

Monopile foundations will occupy a maximum of 0.09% of the seabed area within the proposed site. The faunal/sediment associations within the proposed development are widespread throughout the wider Thames estuary and are typical of the southern North Sea region, and therefore are not significantly threatened by the development.

6.4.2. License conditions

Standard monitoring periods were specified within the licence (Table 1). The applicant was referred to existing guidelines on the conduct of benthic surveys for recommendations on the number and location of sampling sites.

6.4.3. Survey Techniques

Sub-tidal. 46 stations within and around the proposed development site and cable route were sampled using a Hamon grab. Ten 2m beam trawls and 11 oyster dredges were conducted to sample epifauna.

Inter-tidal. A walk-over study was performed on the inter-tidal area around the proposed landfall site of the cable. Species, habitats and biotopes were identified and mapped according to standard procedures (Hiscock, 1996; Connor et al., 1997).

6.4.4. Results

Sub-tidal. The pattern of sediment distribution across the survey area has been maintained over time. Temporal variations within each impact area were not significant, each area retaining a high degree of similarity between years. The general distribution of the main macrofaunal assemblages has not changed significantly over the monitoring period. Temporal variations observed were attributed to natural variability.

Inter-tidal. Three habitats were identified, with characteristic species. These were barren gravel, shingle and sand towards the upper and middle shore, lugworm dominated muddy sand on the lower shore and algal, mussel and barnacle dominated surfaces on adjacent rocky surfaces. The available rock substrate was the remains of the foundations of a now extinct peer projecting into the sea. No post-cable installation data was supplied.

6.4.5. Reviewer's comments

While an appropriate quantity of good quality data has been gathered, some of the conclusions or interpretations do not seem to be supported by the information in the report. Lack of sound statistical evidence on the spatial and temporal differences in macrofaunal assemblage parameters between factors prevents the assessment from being deemed completely accurate. The report falls short of the objective of accurately assessing changes in the macrobenthic communities due to the construction and operation of the wind farm. Also, in the reports, there is a lack of inter-tidal benthic community data around the cable landfall area as well as from monitoring the colonisation of turbine masts (video observations and analyses with accompanying sample collection for verification and identification), in line with standard monitoring requirements.

6.5. Scroby Sands

Scroby Sands OWF is situated 2km off North Denes, Great Yarmouth, Norfolk, and consists of 30 2MW turbines. Construction started in 2003 and the site became operational in late 2004.

6.5.1. Predicted impacts

The resident benthic assemblage is typical of relatively clean fine sand around the UK. No nationally rare or protected species are expected. The installation of turbines will result in the loss of 17km^2 of natural seabed area, of which 97% is replacement of existing substrate with scour protection material.

6.5.2. License conditions

As the first wind farm to be consented, the licence conditions at this site differed to those used subsequently. A general condition was specified in the licence, with full detail of the monitoring regime, survey techniques, analytical techniques, sample number and their location incorporated within an Annex. Only one pre-construction, and one post-construction survey was carried out.

6.5.3. Survey Techniques

Sub-tidal. A benthic pre-construction survey was undertaken in July 1998, followed by another benthic survey undertaken in July 2005, after the construction. Each survey involved macrofauna and sediment sampling at 38 stations, using a combination of Day grabs and qualitative dredges in 1998 and Hamon Grabs in 2005. Seven benthic epifauna trawls were also taken on each survey.

Inter-tidal. No inter-tidal monitoring was specified within the licence conditions, or carried out as part of the monitoring regime.

6.5.4. Results

Sub-tidal. The results show a general reduction in diversity and biomass in post-construction data when compared with the pre-construction survey. Whether this was due to natural

fluctuation remains uncertain, as a lack of reference stations and long-term baseline data make it impossible to confidently place benthic changes in the context of natural fluctuations.

6.5.5. Reviewer's comments

Taking samples at reference stations on other sandbanks away from possible construction impact may have clarified the reasons behind the observed changes. It is therefore very important to incorporate this approach to the continuation of the monitoring work. It is also important to examine several years of baseline data to be able to assess the impact of this type of constructions with confidence.

7. Lessons Learned

No detrimental effects have been detected at sites monitored so far. Where change has been noted, it is often attributed to natural variation. However, it is important that the limits of what constitutes 'natural variability' are better defined where such conclusions are drawn. This emphasises the importance of long-term data, and also the limitations of obtaining suitable baseline (pre-construction) data under the existing licensing regime. A single baseline survey is insufficient to ascertain the degree of temporal variability in benthic assemblages prior to OWF installation. Similarly, three years post-construction monitoring is considered to be too short a period to determine the potential long-term changes that may result from OWF construction. 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.

Monitoring programmes must be tailored to the impacts predicted in the EIA and their objectives clearly stated, which has not always been the case. FEPA monitoring is prescribed to monitor any change in benthic communities within and around an OWF site by reasonable means. Therefore, if the EIA predicts an unusual impact, a specialised survey must be designed to monitor such impact. Monitoring surveys must not be perceived as a standardised 'one survey fits all' approach. This concept is not always understood within monitoring reports, and should be a consideration throughout the monitoring process, not applied as an after-thought at the end of a monitoring programme.

Statistical analyses do not always appear to be consistent or correct, and can raise questions on the validity of conclusions. Incorrect analyses at one site mean that future cross-site or cross-study comparisons are reduced to the lowest common denominator in analytical quality (as has happened for this review exercise), forcing the loss of important data and information from reports that have done a decent job.

Reporting of the results from monitoring surveys should provide detailed analysis and discussions of data, including discussion on the factors that could be attributable to any change that has been observed due to the construction of OWFs. Consideration of other impacts is important, in order to address any knock-on effects in other areas, e.g. increase scouring. Also consideration ought to be given to linkages to and interactions with other ecological realms, such as fish that prey upon the benthos and birds that prey upon fish. Any changes detected in one realm will likely have knock-on effects on others.

Epifaunal colonisation of monopiles can result in a localised increase in species diversity. Whether this is a 'beneficial' impact, as is often predicted within an EIA, is debatable. In the reviewer's opinion, the use of the term 'beneficial' is highly subjective and must be avoided. The purpose of OWF installation is to provide renewable energy, whether the side-effect of increased local biodiversity is beneficial or not is irrelevant and should not be proposed as

being a bonus or 'added value'. Surveys are conducted to detect change away from naturally occurring conditions; any increase or decrease in localised biodiversity as a result of OWF installation must be documented, and will assist in the decision of what to do with the installation at the end of its operational lifespan (e.g., remove and restore, or leave in place as an artificial reef).

The monitoring surveys undertaken so far have provided a valuable insight into the short-term impacts of Round 1 offshore wind farm construction. The effects of their construction on the benthic habitat are now better understood and the acquired evidence supports the prediction that the wind farms have no detrimental impact on the surrounding benthos. This provides information that can feed into future monitoring programmes required for Round 2 and Round 3, noting that not all evidence compiled so far will be applicable to all future cases.

8. Recommendations

The quality of statistical analyses across monitoring studies is variable. There is no single correct way of analysing data as the appropriateness of analytical techniques employed will depend on the properties and quality of the data and metadata and what hypotheses are to be tested. Because of this, and the apparent ease of use of some widely available analytical applications, it is very easy to get analyses wrong. 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, e.g. signing off of reports by senior scientist or even an informal, internal peer review process. Adoption of such a scheme would ensure that all datasets and results over space and time are compatible and allow future spatial and temporal trends to be investigated properly.

This review has highlighted the limitations of the current infaunal benthic monitoring requirements. They reveal that they do no provide enough information to distinguish observed change from natural variability and have so far only been carried out over a fairly limited time period. Consideration should be given to modifying monitoring requirements to tackle these findings, and these will be addressed in a follow up project to commence late 2009.

To address the limitations in obtaining detailed temporal baseline data and an understanding of natural variability, contractors carrying out these studies should collaborate with national monitoring programmes (such as National Marine Monitoring Programme - NMMP). The outputs of national monitoring programmes can support the interpretation of any community change by informing on whether similar change has been noted regionally or historically. Also, the potential of following the model set up by the aggregate industry to address regional issues should be considered. Regional Environmental Assessments conducted by the aggregate industry are designed to inform site-specific issues to be addressed within EIAs and assess the impacts of aggregate extraction on an regional scale. The use of such a tool independently or in collaboration, could be highly beneficial to the offshore wind farm construction and renewable energy industries in the future. These could possibly be based around the Crown Estates Round 3 proposals for Zonal Assessment Plans.

Longer term datasets are required to ascertain the long-term effects of OWF installation. The application of regional-scale methods to address the highlighted limitations in monitoring strategies can allow the level of site-specific monitoring be considered in terms of the frequency of post-construction infaunal monitoring. In terms of infaunal monitoring, less frequent surveys over a longer period of time are recommended, with more frequent monitoring concentrating on the known 'near-field' and colonisation impacts.

The observed increase in biomass resulting from the introduction of permanent settling substrates is likely to have long-lasting and far-reaching effects on the surrounding benthos. Such effects must be monitored over time scales appropriate to their potential effect (i.e., tens of years), and surveys should be tailored to address issues of concern, such as their potential as 'stepping-stones' for invasive species. 'Stepping stones' could allow the spread of an invasive species, while the wholesale 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. 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.

The objectives of benthic monitoring should be stated clearly at all stages. Monitoring should also be specifically tailored to the predictions made in the EIA. In addition, the regulator must also be clear and consistent in its advice, to minimise the chances of confusion and misguidance.

9. Conclusions

This review has endeavoured to address five key issues (Section 2). Each of these is considered in turn below.

9.1. What has been learned about the effects of offshore wind farms on benthos?

As discussed in Section 7, no detrimental effects have been detected at sites so far. The monitoring surveys undertaken so far have provided a valuable insight into the short-term impacts of Round 1 OWF construction. Where change has been noted, it is often attributed to natural variability; however, the monitoring so far is unable to define the limits of what constitutes 'natural variability'. Similarly, three years post-construction monitoring is considered to be too short a period to determine the potential long-term changes that may result from OWF construction.

Epifaunal colonisation of monopiles can result in a localised increase in species diversity. Whether this is a 'beneficial' impact, as is often predicted, is debatable and highly subjective. The long-term effects of this change are still unknown.

9.2. What has been learned about the adequacy of monitoring and analytical approaches for benthos?

Monitoring programmes must be tailored to the impacts predicted in the EIA and their objectives clearly stated. Also, statistical analyses do not always appear to be consistent or correct, and can raise questions on the validity of conclusions. Monitoring surveys must not be perceived as a standardised 'one survey fits all' approach, and the objectives and other impacts (e.g. linkages with sediment morphology, ecological linkages) should be considered throughout the monitoring programme.

9.3. Recommendations on whether any conditions can be removed (because we now have sufficient information)

The FEPA conditions for benthos 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.

9.4. Recommendations on whether any new conditions or approaches to monitoring/analysis should be adopted.

As discussed in Section 8, to address the limitations in obtaining detailed temporal baseline data and an understanding of natural variability, consideration should be given to incorporating national monitoring programmes and co-ordinated regional assessments into monitoring regimes. The addition of such methods allows the consideration of a programme of less frequent, yet longer term monitoring.

9.5. Recommendations on the need for comparability in datasets and reporting styles

Incorrect statistical analyses at one site mean that future cross-site or cross-study comparisons are reduced to the lowest common denominator in analytical quality, and QA/QC procedures are recommended to avoid this.

The objectives of benthic monitoring should be stated clearly in all reports, at all sites.

10. References

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