Ocean Energy ORJIP working to accelerate offshore consenting

Llywodraeth Cymru Welsh Government

ORJIP Ocean Energy

Information Note: Changes in Oceanographic Systems

Report to: Welsh Government

Issued by Aquatera Ltd and MarineSpace Ltd

P983 – March 2022

aquatera environmental services and products

MarineSpace Making Sense of the Marine Environment™

CONTENTS

Information Note: Changes in Oceanographic Systems

1 INTRODUCTION

This series of technical, topic-specific Information Notes has been co-produced by the Welsh Consenting Strategic Advisory Group's Science and Evidence subgroup (SEAGP) in order to support the consenting of wave and tidal stream energy projects. The Information Notes have been developed to establish the current position of key stakeholders in Wales on the evidence available on interactions of wave and tidal energy technologies with the marine environment. They are designed to set out a starting point for applicants by providing an understanding of where consenting challenges might lie. The aim of the Information Notes is to support marine licence applications that are robust, proportionate and focused on assessing the key potential significant impacts and possible interactions between marine renewable energy (MRE) devices and the marine environment.

These Information Notes will support careful consideration of how, for a particular development, potential impacts that are considered low risk could be safely retired from further detailed consideration within Environmental Impact Assessments (EIA), where available evidence supports this approach. Ocean Energy Systems-Environmental (OES-Environmental) has set out a general process for risk retirement[1,2] but for developments in Welsh waters, risk retirement should always be discussed between developers and Natural Resources Wales (NRW) at the pre-application stage. In the context of these Information Notes, risk retirement implies that all potential impacts are included for consideration at the project scoping stage, and that following a review of the evidence some impacts may be 'scoped out' of any further detailed assessment to focus EIA on key significant impacts[3]. In all cases, potential impacts should be acknowledged in EIAs, with evidence-based justifications describing why particular impacts could be 'scoped out' of further detailed assessment.

Further information about this series of Information Notes, who these documents are for, how they were produced, and how they should be used can be found in the accompanying document *Information Notes: Background*

---

[1] https://tethys.pnnl.gov/events/oes-environmental-webinar-risk-retirement
[2] https://tethys.pnnl.gov/publications/state-of-the-science-2020-chapter-13-risk-retirement
[3] It should be noted that The Wildlife Trusts expressed concerns about the use of the phrase 'risk retirement' being applied in this context, particularly considering the uncertainties in impact assessment that are likely to arise with increasing scale of MRE developments.

Information. The *Information Notes: Background Information* documentation also contains information about the terminology used in this document.

1.1 CHANGES IN OCEANOGRAPHIC SYSTEMS – GENERAL

Marine renewable energy (MRE) developments are generally situated in high energy marine environments. These high energy environments appropriate for tidal energy extraction may be located in or near to constricted channels or near headlands where water velocities and flow rates are high. Meanwhile, high energy environments associated with wave energy development are often found at exposed coastal areas with unobstructed open waters where wave energy is high (Yang and Copping 2017).

MRE devices are designed to remove energy from the marine system in order to generate electricity and it has been suggested that in some configurations this could lead to near field and far field changes in some of the important physical processes in the ocean or along coastlines. These ocean and coastal processes include hydrodynamics, tidal circulation, wave action, sediment transport and temperature and salinity gradients. However, changes to oceanographic systems resulting from large-scale MRE developments need to be viewed within the context of the ocean as a dynamic system. It is important to compare the magnitude of potential changes caused by MRE developments to the natural variation of key parameters in marine systems (Whiting and Chang, 2020).

Tidal turbines deployed in the marine environment could influence tidal circulation and have knock-on effects on the flushing of contaminants from enclosed coastal systems, on sediment transport, and on water column mixing. However, these effects will almost certainly be small until large arrays are deployed and operated (De Dominicis et al. 2017; Nash et al. 2014).

Wave energy converters (WECs) have the potential to alter wave propagation and under-currents, and as such possibly affect natural processes such as the vertical mixing of water column properties and the transport of sediment in coastal waters and the shaping of coastlines (González-Santamaría et al. 2012, 2013). Again, these effects from WEC installation will likely be small until large arrays are deployed and operated (Whiting and Chang, 2020).

'Hydrographical conditions' is one of the 11 descriptors of 'Good Environmental Status' (GES). The requirement for assessment of impacts on oceanographic systems from a project in Welsh waters is driven by the marine licence required, and the need for evidence, where necessary to meet the requirements of the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended). These regulations set out the minimum information to be included in an Environmental Statement (a document which presents the EIA), and this includes a description of how site characteristics and resources, including water, are likely to be significantly affected by the project. Coastal processes assessment is therefore a standard component of the impact assessment process.

In 2018, Natural Resources Wales published Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects[4] which included sections on both wave and tidal developments (Brooks et al. 2018).

1.2 EVIDENCE SOURCES CONSIDERED BY SEAGP

SEAGP members were asked to apply their expertise and were encouraged to read the OES-Environmental Short Science Summary document[5] on changes in oceanographic systems associated with MRE devices in advance of providing a response to a questionnaire on this topic. Respondents were also encouraged to consult the full chapter on the same topic within the OES-Environmental 2020 State of the Science Report[6]. Additional key references are listed at the end of this document.

2 VIEWS OF NATURAL RESOURCES WALES ON CHANGES IN OCEANOGRAPHIC SYSTEMS

The information presented in this section was gathered in consultation with Natural Resources Wales (NRW) specialists including those for coastal processes, benthic and seabed habitats, fish, seabirds, and marine mammals.

2.1 GENERAL PERSPECTIVES ON CHANGES IN OCEANOGRAPHIC SYSTEMS

For all receptors (coastal processes, benthic habitats and invertebrates, marine mammals, seabirds and fish), the risk of changes in oceanographic systems from MRE developments is likely to increase with the scale of the development. Assessing the level and significance of a likely impact becomes more difficult as developments increase in scale. Larger developments may have greater potential to modify the ocean and coastal physical processes that characterise marine benthic and pelagic habitats and may have associated impacts on the organisms that make use of them.

Many of the impacts that NRW receptor specialists identify are secondary effects, for example changes in prey distribution or habitat use by fish,

---

[4] https://cdn.naturalresources.wales/media/689057/guidance-on-best-practice-for-marine-and-coastal-physical-processes-baseline-survey-and-monitoring-requirements-to-inform-eia-of-major-developement-projects.pdf

[5] https://tethys.pnnl.gov/summaries/short-science-summary-changes-oceanographic-systems

[6] https://tethys.pnnl.gov/publications/state-of-the-science-2020-chapter-7-oceanographic-systems

seabirds, or marine mammals associated with changes to the oceanographic system.

NRW's overall perspective on the general level of environmental risk associated with changes to oceanographic systems can be found in Table 1.

Table 1. NRW perspectives on the general level of environmental risk* associated with changes to oceanographic systems for generic development scenarios

Deployment scale	Very low	Low	Intermediate	High	Very high
Single device		✓			
Small array			✓		
Large array				✓	

**Note that risks to seabed habitats are, by their nature very site-specific. This table should be treated as a general indication of relative risk.*

2.1.1 Factors influencing changes in oceanographic systems

NRW identify several factors that would influence the degree of changes to oceanographic systems, including the type of device, the scale of the array, and the location. Different wave and tidal energy devices have varying amounts of infrastructure placed on the seabed and in the water column and are therefore likely to have different effects on oceanographic systems, although at present NRW note there is limited evidence profiling the impacts of different device types.

For devices where the scale of changes to oceanographic systems is reduced, the perceived level of impact may be lower.

For all receptors, location is an important factor influencing the level of importance of changes to ocean and coastal processes as an effect from MRE deployments, particularly with respect to Marine Protected Areas (MPAs). Should a development overlap with an MPA, it could negatively impact on protected features, depending on what the MPA is designated for. However, NRW highlight that a development's zone of impact may cover a larger area than the development's footprint. Developments not overlapping with MPAs may still impact nearby MPAs indirectly via changes in physical processes such as significant wave height and sediment deposition. The influence of location on overall risk therefore depends on the ways in which habitats and animals respond to or use a particular area.

2.1.2 Status of the evidence base and requirements for data collection

For all receptors, NRW suggest that the evidence base is sufficient for decision-making at single device scales, but that greater uncertainty is associated with

small and large arrays. It is likely that NRW would require project-specific information to support an EIA at all scales, and in-depth data collection would be required for coastal processes and benthic receptors. In-depth data collection in the context of changes to oceanographic systems would only likely be required by NRW for fish, seabirds, and marine mammals at large array scales.

2.1.3 Priority for research and monitoring

NRW suggest that changes to oceanographic systems are generally of low to moderate priority for research and monitoring campaigns. Among the receptors profiled in the remainder of Section 2, the greatest priority for research on this topic is associated with effects of changes to oceanographic systems on coastal processes and seabed habitats.

2.2 COASTAL PROCESSES

NRW perceive the importance of impacts on coastal processes from changes to oceanographic systems to be 'very low' for single MRE device installations, although they note that increasing the scale of development will increase the importance of impacts to both coastal processes and benthic habitats (Table 2).

Increasing energy extraction and wave interference associated with larger deployments will have larger effects on coastal processes. For large arrays, NRW suggest that array layout and proximity to the coast will impact on coastal processes by altering wave and current regimes, leading to potential alteration of sediment transport pathways and increased turbulence.

Table 2. NRW perspectives on the importance of oceanographic change as an effect on coastal processes and on the status of the current evidence base

Deployment scale	Importance*	Available evidence base
Single device	Very low	Very good
Small array	Low	Adequate
Large array	Intermediate, but location dependent	Poor

**the scale for relative importance is 'negligible, very low, low, intermediate, high, very high'*
***the scale for evidence base is 'very poor, poor, adequate, good, very good'*

Depending on the habitats present in a development area, and whether there is permanent loss of habitat due to impacts on coastal processes, the importance of effects from arrays could rise to intermediate.

2.2.1 Factors influencing effects on coastal processes

The topography surrounding a development site will also influence the degree of effects on coastal processes from MRE developments. For example, tidal energy developments situated off headlands may have a reduced impact on coastal processes in comparison with developments along open coastlines or situated in front of a bay. Where arrays are sited further offshore, the impact to coasts caused by reduction in flow velocities, current alterations, and the focusing of wave energy into localised areas is likely to be reduced, thereby posing reduced environmental risk.

In relation to coastal processes, NRW suggest that floating tidal platforms could reduce the direct loss of habitat and impacts on sediment transport. However, floating tidal devices could also act as barriers, with greater influence on wave interference, diffraction, and wave reduction on the sheltered (or landward) side of devices. These effects could lead to wave energy becoming focused in some areas along different parts of the coastline.

NRW highlight that wave energy converters are designed to remove energy from waves and so may directly reduce wave energy and wave height on the sheltered, or landward side of the device(s), resulting in less wave energy reaching the coast. Surface turbulence could still be generated around wave energy devices but floating wave energy devices would likely have lower impact on the seabed as a result of a reduced seabed footprint.

2.2.2 Status of the evidence base and requirements for data collection

For single device deployments, NRW consider the available evidence base for coastal processes to be satisfactory to inform advice and support decision-making (Table 2). However, as developments grow in size the evidence base is reduced and there is an increasing reliance on modelling for coastal process impact assessment. For large arrays, there is uncertainty relating to the complex interactions between wave, current, and sediment transport which are often over-simplified by desk-based modelling. There is very little complementary in-situ evidence available to validate the hydrodynamic or sediment transport-related assumptions incorporated into such models.

It would be very likely that effects on coastal processes would be scoped into EIAs for all MRE development scales. NRW have produced guidance to inform data collection for such assessments:

- GN 41 Marine Physical Process Guidance to Inform EIA[7]

[7] https://cdn.cyfoethnaturiol.cymru/media/692263/marine-physical-processes-guidance-to-inform-environmental-impact-assessment-eia.pdf

- GN 06 Marine ecology data sets for marine developments and activities[8]

Included in this guidance are monitoring strategies such as site surveys during operation of MRE devices to monitor seabed morphology, in-situ measurements of current velocities and direction using acoustic doppler current profilers (ADCPs), and wave height and direction measurements using a wave rider buoy. For a single device, these monitoring strategies would not be required to meet consent conditions, however, they could be used to improve understanding of how different device types change hydrodynamic and sediment transport processes.

2.3 BENTHIC HABITATS AND INVERTEBRATES

The level of risk and potential impacts to benthic habitats are linked to the modifications in coastal processes that result from changes to oceanographic systems. Risk will also vary with the type and amount of infrastructure placed in the water and on the seabed, as discussed in Section 2.2. Larger arrays are expected to have greater potential to modify the benthic environment through changes in current flows at the seabed, sediment transport, scour, deposition and other physical processes. The resulting risk associated with this effect, and therefore its importance is likely to increase with development scale (Table 3), depending on whether any effects impact features sensitive to change or MPAs.

Table 3. NRW perspectives on the importance of oceanographic change as an effect on seabed habitats and invertebrates and on the status of the current evidence base

Deployment scale	Importance*†	Available evidence base
Single device	Low	Adequate
Small array	Low-Intermediate	Poor
Large array	Intermediate	Very poor

**the scale for importance is 'negligible, very low, low, intermediate, high, very high'*
***the scale for evidence base is 'very poor, poor, adequate, good, very good'*
†Note that effects for seabed habitats and associated faunal communities are highly dependent on location, particularly proximity to protected features or habitats.

2.3.1 Factors influencing effects on seabed habitats and invertebrates

The physical conditions at the development site (e.g. type of sediment, tidal currents) will have a strong influence on the level of risk and likely impacts on benthic habitats. NRW highlight that it is important to understand the sensitivity of the benthic habitats within the zone of impact of a proposed development. When undertaking assessments, consideration should be given to features

[8] https://naturalresources.wales/guidance-and-advice/business-sectors/marine/marine-ecology-datasets-for-marine-developments/?lang=en

protected by MPAs under the Conservation of Habitats and Species Regulations 2017 and to habitats and species outside of MPAs that are protected under Section 7 of the Environment Wales Act (2016). This is because the overarching aim of the Conservation of Habitats and Species Regulations 2017 is to achieve 'favourable conservation status' of protected habitats, and this aim relates to the entire occurrence of a habitat type within its natural range rather than applying only to the occurrences within the MPA network.

2.3.2 Status of the evidence base and requirements for data collection

NRW's perspective is that for benthic habitats, the available evidence base on changes to oceanographic systems may be sufficient to support decision-making at the single device scale. However, more evidence is required to support decision-making at larger development scales. For most developments, site-specific information would be required to inform modelling of physical processes, as set out in Section 2.2. The outcomes of modelling would help to inform the scope and spatial extent of benthic impact assessments.

NRW would expect developers to undertake a baseline characterisation survey to inform EIA and Habitats Regulations Assessment (HRA), apart from in a very few cases where seabed surveys have recently been undertaken. The zone of influence of a development should be determined through physical processes modelling.

For benthic habitat assessment approaches and methods NRW recommend that developers consult the following guidance:

- GN 030 Benthic habitat assessment guidance for marine developments and activities[9]
- NRW Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects (Brooks et al. 2018)[10]. Section 6.4.1 of this document includes guidance to ensure that particle size analysis requirements from benthic surveys are compatible with physical process requirements.
- JNCC Monitoring Guidance for Marine Benthic Habitats (Noble-James et al. 2018)

[9] https://naturalresources.wales/guidance-and-advice/business-sectors/marine/benthic-habitat-assessments-for-marine-developments/?lang=en

[10] https://cdn.naturalresources.wales/media/689057/guidance-on-best-practice-for-marine-and-coastal-physical-processes-baseline-survey-and-monitoring-requirements-to-inform-eia-of-major-developement-projects.pdf.

2.3.3 Mitigation strategies

Several mitigation strategies could be used to manage effects on benthic habitats from changes in oceanographic systems. Implemented measures for seabed habitats should be linked to those for coastal processes, given their close interaction. These mitigation strategies include:

- Micro-siting of export cables and infrastructure,
- Micro-siting of landfall cables and infrastructure,
- Best practice methodologies to reduce resuspension of sediment during cable burial, or device foundation or mooring installation,
- Pre and post installation monitoring of sensitive benthic communities using divers, drop-down video, static cameras, remote sensing, or grab sampling,
- Geophysical surveys to identify scour pits, and turbidity measurements - surveys should consider both offshore and intertidal areas.

2.4 FISH

From NRW's perspective, effects on fish from changes to oceanographic processes resulting from MRE deployment depend on the fish species present at the development site, how those fish use the habitat in question, and how the change in hydrodynamics could affect those habitats.

Although this effect is of relatively low risk to fish, any effects could be higher in a large array scenario.

Table 4. NRW perspective on the importance of oceanographic change as an effect on fish and on the status of the current evidence base

Deployment scale	Importance*†	Available evidence base
Single device	Negligible	Adequate
Small array	Negligible	Adequate
Large array	Very low	Poor

**the scale for importance is 'negligible, very low, low, intermediate, high, very high'*
***the scale for evidence base is 'very poor, poor, adequate, good, very good'*
†Note that the importance is highly dependent on factors such as effects on protected habitat, array size, and magnitude of changes to physical processes

2.4.1 Status of the evidence base and requirements for data collection

NRW consider that the evidence base to support decision-making is satisfactory for single devices and small arrays. However, for large arrays NRW consider that the evidence base is less certain because effects on fish species using habitats in development sites are less clear (Table 4).

For fish, specific data collection to understand effects would likely be required for large arrays, depending on the footprint of the impact, the location of the devices, and the ways in which fish use the area.

2.4.2 Mitigation strategies

For fish, NRW agree that micro-siting could be an appropriate mitigation strategy, if carried out to 1) reduce hydrodynamic effects or 2) to move any effects away from sensitive areas for fish. Suggested additional management measures included using hydrodynamic modelling to gain an understanding of how fish use the proposed development site and using this information to inform the project design.

2.5 SEABIRDS

The importance of changes to oceanographic processes from MRE devices is generally very low for potential effects on seabirds (Table 5). However, NRW advise that should desk-based modelling predict habitat changes resulting from larger arrays there may be greater effects on seabird foraging, thereby increasing the importance of this effect.

Table 5. NRW perspectives on the importance of oceanographic change as an effect on seabirds and on the status of the current evidence base

Deployment scale	Importance*†	Available evidence base
Single device	Very low	Adequate
Small array	Very low to low, dependent on impacts on seabird foraging from habitat change	Adequate
Large array	Very low to low, dependent on impacts on seabird foraging from habitat change	Adequate

**the scale for importance is 'negligible, very low, low, intermediate, high, very high'*
***the scale for evidence base is 'very poor, poor, adequate, good, very good'*
†Note that the importance is highly dependent on factors such as effects on protected habitat, array size, and magnitude of changes to physical processes

The level of information available to support decision-making on this impact pathway for seabirds is currently adequate for developments at all scales. It is possible that this effect may be 'scoped out' for further detailed assessment in an EIA at single device and small array scales.

2.6 MARINE MAMMALS

For single devices, NRW suggest that the importance of changes to oceanographic systems for marine mammals are negligible (Table 6). At present, there is no evidence of any changes in oceanographic conditions influencing marine mammals, although there has been limited opportunity to

observe changes for developments larger than a single device. This effect could become more important for larger array deployments.

2.6.1 Factors influencing effects on marine mammals

Any impacts on marine mammals from changes in oceanographic processes are likely to arise through direct impacts to prey species or through impacts on the use of a particular habitat by a prey species.

NRW identify that for development sites in the vicinity of or overlapping an MPA, any impacts or losses to a particular marine mammal management unit would be assumed to be linked to that MPA because of functional linkages between the animals and the MPA. It should be noted that a deployment close to a marine mammal MPA is likely to be closer to a high-density area for marine mammals.

Table 6. NRW perspective on the importance of oceanographic change as an effect on marine mammals and on the status of the current evidence base

Deployment scale	Importance*†	Available evidence base
Single device	Negligible	Adequate
Small array	Very low	Adequate
Large array	Very low	Poor

**the scale for importance is 'negligible, very low, low, intermediate, high, very high'*
***the scale for evidence base is 'very poor, poor, adequate, good, very good'*
†Note that the importance is highly dependent on factors such as effects on protected habitat, array size, and magnitude of changes to physical processes

2.6.2 Mitigation strategies

NRW indicate that at present there are not any recommended management or mitigation measures for changes to oceanographic processes and subsequent effects on marine mammals, although hydrodynamic modelling could provide insight into potential impacts on prey species.

3 PERSPECTIVES FROM ENVIRONMENTAL ORGANISATIONS

In responding to this Information Note, both the Royal Society for Protection of Birds (RSPB) and The Wildlife Trusts (TWT) identify that the effects of changes to oceanographic systems associated with MRE development are somewhat outside their areas of expertise or current focus. However, both organisations note that any secondary impacts on receptors resulting from oceanographic changes would be of concern for them.

TWT highlight that it will be valuable to understand any alterations to physical process such as sediment transport and upwelling in order to identify indirect

effects on receptors. RSPB emphasise that for seabirds, for example, oceanographic changes resulting in prey displacement would be of relevance, as would changes in water movement affecting the diving behaviour of seabirds. Both organisations recognise that research into these topics is at very early stages, and that it could become a more relevant area for research in the future.

4 PERSPECTIVES FROM INDUSTRY

Industry members views on this topic are generally very similar to NRW's. They perceive changes to oceanographic systems from MRE developments to be of very low risk, and therefore of lower importance in terms of the level of EIA assessments, although there would be some dependency on site topography. For example, a small array deployed in a narrow or restricted channel could result in greater effects than the same array deployed in a large channel.

The effects of large arrays are expected to be more important for some receptors such as seabed habitats, where hydrodynamic changes could impact sediment transport and/or deposition processes.

Industry members suggest that effects from tidal stream energy developments could be more substantial than for wave energy developments, as the extraction of energy from tidal currents by large tidal energy arrays could affect turbulence and mixing in enclosed basins, with potential secondary effects on some receptors. Wave energy is a substantially more dispersed resource, and any effects from wave energy converters on oceanographic processes are suggested to be negligible in comparison with natural, seasonal, and climatic variation, unless very large arrays of WECs were deployed.

4.1 STATUS OF THE EVIDENCE BASE AND REQUIREMENTS FOR DATA COLLECTION

Like NRW, industry consider that there is sufficient evidence to support decision-making on this effect for single devices, but they are less confident in the evidence base for small and large arrays. For large arrays, members also highlight the current reliance on the outputs of hydrodynamic models as a basis for determining effects. These models are well refined to predict changes in physical parameters, but not effects on ecological receptors. Attribution of effects on ecological receptors to changes in oceanographic processes is currently challenging.

At present, members would not expect project-specific data collection to be necessary for single device deployments but suggest that this effect is still somewhat likely to be 'scoped in' to an assessment.

Changes to oceanographic systems are perceived to be of moderate priority for research and monitoring. Industry members noted that with increasing scale of

deployments it will be essential to collect data around developments using strategies such as those outlined in the OES-Environmental State of the Science 2020 report (Whiting and Chang, 2020).

5 SUMMARY AND RECOMMENDATIONS

Changes to oceanographic systems are generally considered to be of low to intermediate importance relative to other effects from MRE developments, however, this effect is likely to increase in priority as wave and tidal stream energy developments grow in scale and number.

Although deployments of multiple, large arrays in Welsh waters are set to occur several years into the future, it will be valuable to gather relevant data from small arrays to continue to improve hydrodynamic models and validate associated assumptions and model outcomes. Continued improvements to hydrodynamic models will ensure that at the time of large-scale build-out, these models will be sufficiently well-developed to provide accurate assessments of any effects on oceanographic systems.

As multiple arrays develop around the UK coastline, understanding how changes in hydrodynamics resulting from individual arrays will become more relevant. Hydrodynamic modelling studies have suggested that that it is critical to consider array design in the planning stages as deployments scale up (Waldman et al. 2019).

An understanding of how habitats and animals respond to changes in oceanography will also be valuable as arrays increase in size and number. At present, it is difficult to attribute secondary effects on receptors to hydrodynamic changes for small developments. As MRE developments increase in scale, these effects will become increasingly important, but should also be considered against the backdrop of a changing climate experiencing warming oceans and rising sea levels (Whiting and Chang, 2020).

The offshore wind energy industry is now beginning to examine secondary effects on receptors through programmes such as the Crown Estate's Offshore Wind Evidence and Change Programme[11]. There may be opportunities for the MRE sector to learn from such programmes and to apply similar approaches to future research and monitoring of developments.

5.1 RECOMMENDATIONS

- There are some discrepancies in expectations between stakeholders as to the level of detail required to address changes to oceanographic systems in EIAs.

[11] https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-evidence-and-change-programme/

Good communication between developers and NRW, statutory consultees, and environmental organisations at an early stage would help to identify the level of assessment required for this effect on a case-by-case basis.

- There is an evidence gap in understanding how habitats and animals respond to changes in oceanography. Data collection across extensive sea area is needed to address this data gap to separate effects from MRE installations from those associated with other human activities and natural variability. By collaborating and pooling resources and data with other initiatives such as the Offshore Wind Evidence and Change Programme, this evidence gap could be addressed in a more strategic fashion.
- Evidence on secondary effects on receptors from changes to oceanographic systems and other cumulative impacts is emerging from other marine industries. This evidence should be considered and applied as appropriate in the MRE sector.

6 REFERENCES

NOTE THAT ADDITIONAL REFERENCES ARE INCLUDED THAT ARE NOT CITED IN THIS INFORMATION NOTE

Brooks, AJ., Whitehead, PA., Lambkin, DO. 2018. Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects. NRW Report No: 243, 119 pp, Natural Resources Wales, Cardiff. Available online at: https://cdn.cyfoethnaturiol.cymru/media/689057/guidance-on-best-practice-for-marine-and-coastal-physical-processes-baseline-survey-and-monitoring-requirements-to-inform-eia-of-major-developement-projects.pdf

De Dominicis, M., O'Hara Murray, R., and Wolf, J. 2017. Multi-scale ocean response to a large tidal stream turbine array. Renewable Energy, 114, 1160-1179. doi:10.1016/j.renene.2017.07.058 https://tethys.pnnl.gov/publications/multi-scale-ocean-response-large-tidal-stream-turbine-array.

González-Santamaría, R., Zou, Q., and Pan, S. 2012. Modelling of the Impact of a Wave Farm on Nearshore Sediment Transport. Proceedings of 33rd Conference on Coastal Engineering, Santander, Spain. doi:10.9753 /icce.v33.sediment.66. Available online at: https://tethys.pnnl.gov/publications/modelling-impact-wave-farm-nearshore-sediment-transport

Gonzalez-Santamaria, R., Zou, Q. P., and Pan, S. 2013. Impacts of a Wave Farm on Waves, Currents and Coastal Morphology in South West England. Estuaries and Coasts, 38(1), 159-172. doi:10.1007/s12237-013-9634-z . Available online at: https://tethys.pnnl.gov/publications/impacts-wave-farm-waves-currents-coastal-morphology-south-west-england

Nash, S., O'Brien, N., Olbert, A., and Hartnett, M. 2014. Modelling the far field hydro-environmental impacts of tidal farms – A focus on tidal regime, inter-tidal zones and flushing. Computers & Geosciences, 71, 20-27. doi:10.1016/j.cageo.2014.02.001 https://tethys.pnnl.gov/publications/modelling-far-field-hydro-environmental-impacts-tidal-farms-focus-tidal-regime.

Noble-James, T., Jesus, A. & McBreen, F. 2018. Monitoring guidance for marine benthic habitats (Revised 2018). JNCC Report No. 598. JNCC, Peterborough. Available online at: https://data.jncc.gov.uk/data/9ade4be8-63dd-4bbc-afd0-aefe71af0849/JNCC-Report-598-REVISED-WEB.pdf

Waldman, S., Weir, S., Murray, R.O.H., Woolf, D.K. and Kerr, S., 2019. Future policy implications of tidal energy array interactions. Marine Policy, 108, p.103611.

Whiting, J.M. and G. Chang. 2020. Changes in Oceanographic Systems Associated with Marine Renewable Energy Devices. In A.E. Copping and L.G. Hemery (Eds.), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). (pp. 127-145). DOI: 10.2172/1633183.

Yang, Z., and Copping, A. 2017. Marine Renewable Energy: Resource Characterization and Physical Effects. Springer International Publishing. https://tethys.pnnl.gov/publications/marine-renewable-energy-resource-characterization-physical-effects.

APPENDIX A ADDRESSING CHANGES IN OCEANOGRAPHIC SYSTEMS IN PREVIOUS MARINE ENERGY PROJECTS: LICENSING DOCUMENTS AND CONSENT CONDITIONS

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
Mey Gen	Scotland	Tidal Stream Array	Constructed	Sediment transport modelling study was adopted as sediment within the region has the potential to impact other receptors indirectly if the installation of the array were to fundamentally change the flow patterns in the Inner Sound - The mobility of the seabed is dependent on the local current and wave conditions, and the local sediment characteristics.	Environmental Statement	
Mey Gen	Scotland	Tidal Stream Array	Constructed	For physical oceanographic environment and sediment dynamics, a significance criterion for the sensitivity of receptor and magnitude of impact was used.	Environmental Statement	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
Morlais	Wales	Tidal Stream Demo Zone	Consented	Scour monitoring	Marine Licence	The Licence Holder must submit a specification for construction and post-construction monitoring surveys to the Licensing Authority for written approval at least 4 months prior to the commencement of Licensed Activities. The monitoring specification must include scour monitoring unless otherwise agreed with the Licensing Authority.
Dounreay Tri	Scotland	Floating Offshore Wind	Consented	Changes to local sediment transportation processes and seabed features due to altered hydrodynamics related to interactions between mooring cables, anchors and cables with action of water currents and waves were considered negligible when a significance criterion for the sensitivity of receptor and magnitude of impact was used.	Environmental Statement	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
Hywind Scotland	Scotland	Floating Offshore Wind	Consented	Site selection of deep water at the turbine deployment area resulting in wave action being unlikely to influence scour.	EIA	
Hywind Scotland	Scotland	Floating Offshore Wind	Consented	Contribution of a number of specialists to the assessment of the physical oceanographic environment, including: MMT - seabed survey, video footage analysis, biotope mapping, seabed survey reporting; GEO - geotechnical survey, soil analysis, survey reporting; Statoil - met ocean design; and Xodus - landfall site walkover, geotechnical evaluation, geotechnical desk study report, phase 1 intertidal survey report, baseline description, impact assessment and ES chapter.	EIA	
Kincardine	Scotland	Floating Offshore Wind	Consented	Site selection of deep water at the development area resulting in wave action at the site is unlikely to influence movement of sediments on the seabed.	EIA	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
Kincardine	Scotland	Floating Offshore Wind	Consented	Changes to local sediment transportation processes and seabed features due to altered hydrodynamics related to interactions between mooring cables, anchors and cables with action of water currents and waves were considered not significant during an impact significance assessment.	EIA	
DeltaStream	Wales	Tidal Stream Energy Demonstration Array	Consented	In terms of sediment being lifted into the water currents, no digging of the seabed is required, and this will minimise suspended sediments. Any coarse sediment lifted into the water when the various components come to rest on the seabed will settle quickly. All boats will follow recognised industry standards so that the potential risk to water quality can be reduced as far as is practically possible.	EIA DeltaStream Demonstrator Project Ramsey Sound, Pembrokeshire (pnnl.gov)	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
DeltaStream	Wales	Tidal Stream Energy Demonstration Array	Consented	During operation there will be a minor reduction in tidal flow downstream, but this effect is likely to be small compared to the existing turbulence that is present in this high energy environment. In terms of larger waves there will be a slight reduction of their ongoing height. However, this is likely to be insignificant due to the local water depth and the small nature of the DeltaStream structure sitting highest in the water column (the rotors' blade tips).	EIA DeltaStream Demonstrator Project Ramsey Sound, Pembrokeshire (pnnl.gov)	
META	Wales	Wave and Tidal Demo Zone	Consented	Changes in hydrodynamics associated with tidal devices were considered negligible when a significance criterion for the sensitivity of receptor and magnitude of impact was used.	EIA	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
META	Wales	Wave and Tidal Demo Zone	Consented	Site 6 is the only META site where tidal current devices will be deployed for the testing of scaled and micro tidal power devices on a short-term basis (< 6 months). MEW used previous studies of MRE which determined that even installations at full scale with a limited number of devices have a marginal influence on tidal flows, and large-scale arrays are required to produce significant changes - e.g., Strangford Lough (Marine Current Turbines (MCT), 2005) a twin turbine was installed with each rotor being of 16 m diameter. The impact of turbine operation of near field flows downstream of the rotors was found to be negligible, based on Computational Fluid Dynamics (CFD) modelling and observations from the Seaflow prototype.	EIA	
Moray Offshore Renewables (Moray East)	Scotland	Offshore Wind	Consented	Changes to the tidal regime due to the presence of the turbine foundations was assessed using significance criteria for the sensitivity of receptor and magnitude of impact which was found to be negligible	EIA	

Project Name	Location	Technology	Consenting Status	How changes to oceanographic systems are addressed	EIA / HRA / Other	Consent Conditions
Moray Offshore Renewables (Moray East)	Scotland	Offshore Wind	Consented	Changes to the wave regime due to the presence of the turbine foundations was assessed using significance criteria for the sensitivity of receptor and magnitude of impact which was found to be negligible.	EIA	
Moray Offshore Renewables (Moray West)	Scotland	Offshore Wind	Consented	Changes to local sediment transportation processes and seabed features due to altered hydrodynamics related to interactions between mooring cables, anchors and cables with action of water currents and waves were considered not significant during an impact significance assessment.	EIA	

ISBN 978-1-80364-179-9