



Environmental Statement Chapter 8. Intertidal and Subtidal Benthic Ecology

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8.0 Intertidal and Subtidal Benthic Ecology

8.1 Introduction

- 8.1.0.1 This chapter provides an assessment of the likely significant effects of the Project on intertidal and subtidal benthic ecology. The following sections detail the methodology by which this assessment has been carried out, provide a baseline description of the intertidal and subtidal ecology and offer an assessment of the likely significant effects that could arise from all stages of the Project. Receptors discussed in this chapter include plankton, macroalgae, intertidal ecology and subtidal ecology.
- 8.1.0.2 The works associated with the Project that may affect intertidal and subtidal benthic ecology include the Offshore Works, the Cable and Grid Connection Works and the Access Works. Of these it is considered that the effect of the Cable and Grid Connection Works need not be considered further since the proposed engineering solution to be deployed are either the use of existing conduits, involving no works of intertidal or subtidal areas or direct drilling, which will pass beneath the channel of the River Neath and will have only a direct effect in the immediate area where the drill enters the ground, which will be land-based.
- 8.1.0.3 Figures relating to this chapter are presented in Volume 2 and technical appendices in Volume 3 of the ES.

8.2 Legislation, planning policy and guidance

- 8.2.0.1 A range of legislation, policy and guidelines applies to the protection of marine habitats and species, which is of relevance to this topic as the object of such protection includes birds and other species that prey on intertidal and subtidal ecology or whose habitats are dependent upon such receptors. At European Union (EU) and international level the most relevant requirements include the EU Birds Directive (2009/147/EC) and the EU Habitats Directive (92/43/EEC), as well as the 1972 Ramsar Convention on Wetlands of International Importance. These have been transposed into UK legislation through various Acts and Regulations, to protect Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar sites. "European Marine Site" (EMS) is the collective term for SACs and SPAs that are covered by tidal water (continuously or intermittently). In accordance with Government advice in both England and Wales, Ramsar sites must be given the same consideration as European sites.
- 8.2.0.2 European Protected Species are species of plants and animals (other than birds) protected by law throughout the European Union. They are listed in Annex IV of the European Habitats Directive, and transposed into UK law by the Conservation of Habitats and Species Regulations 2010.
- 8.2.0.3 The Water Framework Directive (WFD) establishes a framework for the management and protection of Europe's water resources. It is implemented in England and Wales through the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 (the Water Framework Regulations). The aim of the WFD is to achieve "good ecological and good chemical status" in all inland and coastal waters by 2015 unless alternative objectives are set or there are grounds for derogation. Ecological status is an expression of the quality of the structure and functioning of surface water ecosystems as indicated by the condition of a number of "quality elements". These

include hydro-morphological, chemical and biological indicators (including benthic invertebrates, macroalgae, fish, phytoplankton and angiosperms).

- 8.2.0.4 The Marine Strategy Framework Directive (MSFD) aims to achieve Good Environmental Status (GES) in Europe's seas by 2020. GES involves protecting the marine environment, preventing its deterioration and restoring it where practical, while using marine resources sustainably. The Directive sets out 11 high-level Descriptors of GES which cover all the key aspects of the marine ecosystem and all the main human pressures on them. The European Commission has also produced a Decision document (Commission Decision 2010/477/EU) which provides more detailed criteria and indicators of GES which Member States must use when implementing the Directive. The Directive came into force on 15 July 2008, and was transposed into UK law via the Marine Strategy Regulations 2010.
- 8.2.0.5 The Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention) included the establishment of a list of threatened and/or declining species and habitats. This list provides an overview of the biodiversity in need of protection in the North-East Atlantic and is being used by the OSPAR Commission to guide the setting of priorities for further work on the OSPAR Convention and protection of marine biodiversity OSPAR Convention protected habitats and species.
- 8.2.0.6 The Marine and Coastal Access Act 2009 allowed for the creation of a new type of Marine Protected Area (MPA), called a Marine Conservation Zone (MCZ). MCZs protect a range of nationally important marine wildlife, habitats, geology and geomorphology and can be designated anywhere in English and Welsh inshore and UK offshore waters. Sites are selected to protect not just rare and threatened habitats and/or species, but the full range of marine wildlife (JNCC, 2013a).
- 8.2.0.7 The UK Government consulted on the first round of recommended Marine Conservation Zones (rMCZs) in English Inshore and English and Welsh Offshore Waters between 13 December 2012 and 31 March 2013. On 21 November 2013, Defra announced the designation of 27 MCZs around England's coast. In addition it also announced that two further phases of MCZs will be designated over the next three years. A consultation on the next phase is expected to be launched in early 2015 (Defra, 2013).
- 8.2.0.8 In Welsh inshore waters, it was originally proposed that a small number of Highly Protected MCZs would be identified through the Marine Conservation Zone Project Wales. However, following on from consultation undertaken in 2012 on MCZs in Welsh inshore waters, the Welsh Government has withdrawn the 10 initially proposed MCZ sites and are instead now looking to understand more about the wide range of marine habitats and species that are already protected by a series of 125 MPAs (including Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites) that cover 36% of Welsh seas (Welsh Government, 2013a). On 27 November 2013 the Welsh Government announced the new Wales Marine and Fisheries Strategic Action Plan which outlined the Welsh Government's aims of achieving a coherent and well-managed network of MPAs by 2016. As a first step to improving management the Welsh Government, working with Natural Resources Wales (NRW), announced that they will create an MPA management steering group to agree the priorities for improvement and ensure consistency across Wales (Welsh Government, 2013b).
- 8.2.0.9 The Wildlife and Countryside Act 1981 (WCA 1981) provides the national framework for nature conservation in Great Britain. The WCA 1981 provides for the designation and

management of Sites of Special Scientific Interest (SSSI). These sites are designated to safeguard, for present and future generations, the diversity and geographic range of habitats, species, and geological and physiographical features, including the full range of natural and semi-natural ecosystems and of important geological and physiographical phenomena throughout England and Wales. Various species of marine animals are also protected from being killed, injured or disturbed under provisions in Schedule 5 of the WCA 1981.

- 8.2.0.10 The UK Marine Policy Statement (MPS) is the framework for preparing Marine Plans and taking decisions affecting the marine environment. Adopted by the UK Government, the Scottish Government, the Welsh Government and the Northern Ireland Executive, the MPS is intended to help achieve the shared UK vision for clean, healthy, safe, productive and biologically diverse oceans and seas. The MPS aims to enable an appropriate and consistent approach to marine planning across UK waters, and to ensure the sustainable use of marine resources and strategic management of marine activities from renewable energy to nature conservation, fishing, recreation and tourism.
- 8.2.0.11 Further non-statutory protections are afforded to UK habitats and species through the application of the Biodiversity Action Plan (BAP) which has been implemented to protect biodiversity in line with the 1992 Convention on Biological Diversity. The UK priority list contains 1150 species and 65 habitats requiring special protection. The UK list has been used as a reference to draw up the species and habitats of principal importance in Wales under s42 of the Natural Environment and Rural Communities Act 2006 (NERC 2006). The s42 list contains 504 of the UK priority species which occur in Wales and a further 53 species recognised as Welsh priorities, to make up a list of 557 species of principal importance to Wales with an additional 4 groups/assemblages of species. Of the UK's 65 priority habitats, 51 occur in Wales. An additional 3 marine habitats not on the UK list but identified as a priority in Wales are included on the s42 list, making a total of 54 priority habitats in Wales. The combined list of species and habitats is referred to as the "s42 list for Wales" (Wales Biodiversity Partnership, 2012).
- 8.2.0.12 In 2005, the Swansea Biodiversity Partnership produced a document called "Promoting Swansea's Natural Environment: A Local Biodiversity Strategy and Action Plan". The document provided a strategic framework and series of detailed species and habitat action plans looking at how individuals and organisations could work to try and halt biodiversity loss in Swansea. The Action Plan is currently undergoing a review by the Swansea Biodiversity Partnership; updating actions and incorporating new species and habitats declared of principal importance in Wales by the Welsh Government since 2005.

8.3 Assessment methodology

8.3.1 Study area

8.3.1.1 The study area for intertidal and subtidal benthic ecology is shown in Figure 8.1, Volume 2. The study area is divided by reference to the Offshore Works Area and a Wider Study Area. The Offshore Works comprise the area within the footprint of the Lagoon and the seawalls and extends to include a 200m buffer around the Lagoon seawalls, works within the Neath and Tawe Channels and installation of the dolphin piles. The Wider Study Area is based on the maximum extent of anticipated potential indirect effects from the operation of the Project, which in turn has been used to define the extent of the benthic sampling work undertaken to inform this assessment. This has been defined on the basis of the feasibility modelling which predicted the extent of physical changes (see Appendix 8.1, Volume 3). The extent of the study area has since been re-confirmed by detailed modelling undertaken for the Project (Chapter 6; Coastal Processes, Sediment Transport and Contamination).

8.3.1.2 As can be seen in Figure 8.1, Volume 2, the Wider Study Area extends from just around the Mumbles Headland in the west, to Port Talbot. Therefore, the baseline description of the study area includes the habitats and species within this area with particular emphasis on the Offshore Works Area. The Wider Study Area of the Project also includes the marine ecology of the Tawe and Neath estuaries, which is conceivably susceptible to potential effects resulting from the construction or operation of the Project including the possible provision of a water shuttle from the western landfall to the western bank of the River Tawe.

8.3.2 Data sources

Nature conservation designations

8.3.2.1 Information on the current status of nature conservation designations found in the Swansea Bay area has been sourced from citations for international and national nature conservation designations. Websites accessed during the baseline review and impact assessment between January 2013 and January 2014 include those of the Joint Nature Conservation Committee (JNCC), the Countryside Council for Wales (CCW) (now NRW), Natural England, the Environment Agency, Multi-Agency Geographic Information for the Countryside (MAGIC), the Wales Biodiversity Partnership and the National Biodiversity Network (NBN).

Plankton

8.3.2.2 Data on plankton within Swansea Bay itself is generally limited. However, there is a wider range of information available within the Bristol Channel as a whole. A full desk-based literature review has been undertaken.

Macroalgae

8.3.2.3 A desk-based literature review has been undertaken to describe the distribution of macroalgae within Swansea Bay. In addition, a Phase 1 habitat survey (as described in the intertidal ecology paragraph below) has mapped the presence and extent of macroalgae for the area between the River Tawe and River Neath.

Intertidal ecology

- 8.3.2.4 Benthic ecology within the Bay has been well studied and a full, desk-based literature review has been undertaken. In particular, CCW has produced a biotope map, which involved extensive mapping of the intertidal areas around Wales between 2001 and 2003. This provides a description of the habitats within and adjacent to the Offshore Works and around the Bay as a whole. Further to the CCW biotope map, ABPmer undertook a Phase 1 habitat survey to see if there had been any changes in the habitat distribution recorded on the CCW biotope map in particular for the area between the River Tawe and River Neath. Here the survey noted the presence, distribution and condition of *Sabellaria* reefs adjacent to the Tawe Dock entrance. In addition the survey confirmed the presence and distribution of any nationally important biotopes, protected habitats or rare species both here and across the intertidal area west of the River Tawe round to Mumbles Head. The intertidal survey was conducted between Mean High Water Springs (MHWS) with the seaward boundary following Mean Low Water Springs (MLWS) (or as near as possible depending on surf and surge conditions). The surveys were undertaken on 14-15 January 2013 and 28-29 May 2013, at low water during spring tides (Figure 8.2, Volume 2). The approach was based on the standardised Phase 1 mapping methodology detailed in the Marine Monitoring Handbook, procedural guidance No 3-1 (Wyn & Brazier, 2001) and CCW handbook for marine intertidal Phase 1 survey and mapping (Wyn *et al.*, 2000).
- 8.3.2.5 The mapping was undertaken on foot. Aerial photography and satellite images were taken into the field to create sketch maps. Habitats in the area were mapped as polygons using the European Nature Information System (EUNIS) habitat classes to level 4 or 5. Biotopes, or other notable features, covering less than 5m² were recorded using referenced target notes (details are provided in Appendix 8.2, Volume 3).

Subtidal ecology

- 8.3.2.6 A range of studies has been undertaken to investigate the subtidal ecology of the Port Talbot area of Swansea Bay. These include studies undertaken for the Port Talbot Capital Dredge (ABP Research & Consultancy, 1996; ABPmer, 2010) and the offshore wind farm at Scarweather Sands (United Utilities, 2003).
- 8.3.2.7 Due to the lack of site-specific subtidal benthic ecology data within the Offshore Works and the Wider Study Area, Titan Environmental Surveys were commissioned to undertake a characterisation benthic sampling programme (Appendix 8.1, Benthic Sampling Proposal, Volume 3). In order to gather benthic information across the range of different substrates within Swansea Bay, 27 samples were taken from within the footprint of the Lagoon and 22 samples were taken from the area surrounding the Lagoon, providing a total of 49 benthic samples (Figure 8.17, Volume 2). Additional samples were also collected for Particle Size Analysis (PSA) only, giving a total of 59 samples across the whole area. Metal analysis was also undertaken at 17 of the surveyed sites.
- 8.3.2.8 The samples were collected during the offshore survey between 4 and 7 May 2013. Samples were taken across a range of substrates including sand, gravel, sand and gravel, sandy mud, muddy sand, gravelly sand, fine sand and medium sand. Three benthic grab samples were collected at each site using a refined compact 0.1m² Hamon grab. Each sample was photographed and notes taken on the nature of the sediment and obvious large epifauna recovered by the grab. A 3cm Perspex corer was used to collect a sub

sample from the grab for PSA. A subsample was also removed from the grab sample for analysis of metal contaminants, where appropriate. The remainder of the sample was sieved through a 1mm mesh and the residue stored in separate containers in 4% formalin. One sample from each site was transported to a laboratory for benthic analysis, whilst two further samples were archived for future use. Titan Environmental Surveys (2013) provides full details of the analytical methodology.

8.3.2.9 In addition to the benthic sampling survey, seven epifauna/fish trawls were used to obtain qualitative samples of the epibenthos from across the Swansea Bay area. The epifauna trawls were carried out on 18 June 2013 and comprised approximately 200m trawls using a 2m beam trawl with 5mm cod end mesh. Due to marine licensing only giving permission to briefly retain the catch, counting and identification was carried out on site and photographs of each catch was taken before returning the catch to the sea. The location of the fish trawls are shown on Figure 8.17 (Volume 2). Additional seasonal intertidal and subtidal fish trawls were undertaken in 2013 as part of the fisheries assessment and the findings of these are reported in Chapter 9 and Appendix 9.2, Volume 3.

8.3.2.10 These studies have all been set in the context of nationally and regionally available datasets including UKSeaMap¹ and HABMAP².

8.3.3 Impact assessment methodology

8.3.3.1 To facilitate the impact assessment process, a standard analysis methodology has been applied. This framework has been developed from a range of sources, statutory guidance, consultations and ABPmer's extensive Environmental Impact Assessment (EIA) project experience. The key guidance and regulations that are drawn upon include:

- i. the criteria listed in Annex III of the EC Environmental Assessment Directive (85/337 EEC as amended by 97/11/EC);
- ii. the assessment process developed by statutory conservation agencies to provide advice on operations within European Marine Sites (English Nature, 1998);
- iii. an Environmental Risk Assessment approach developed by ABP Research (ABP Research, 1997); and
- iv. Institute of Ecology and Environmental Management's (IEEM) Guidelines for Ecological Impact Assessment in the UK (IEEM, 2006) and Guidance on Impact Assessment in Marine and Coastal Environments (IEEM, 2010).

8.3.3.2 The environmental issues have been divided into distinct 'receiving environments' or 'receptors'. The effect of the proposed activities on each of these will be assessed by describing in turn:

- I. the baseline environmental conditions of each receiving environment;
- II. the 'impact pathways' by which the receptors could be affected;
- III. the significance of the impacts occurring; and

¹ <http://jncc.defra.gov.uk/page-2117>

² <http://www.ccg.gov.uk/landscape--wildlife/habitats--species/habmap.aspx>

IV. the measures to mitigate significant adverse impacts where these have been predicted (Chapter 2, Section 2.5.5).

8.3.3.3 This Impact Assessment Framework, which is presented in the following sections, is designed to incorporate the key criteria and considerations without being unnecessarily prescriptive.

Stage 1 - Identify features and changes

8.3.3.4 The first stage involves identifying the potential environmental changes resulting from the proposed activities (pressures) and the features of interest (receptors) that are likely to be affected.

8.3.3.5 The combination of the pressure and exposure of each receptor to that pressure is referred to as the impact pathway. This aspect of the assessment has been developed in consultation with key statutory and non-statutory authorities.

8.3.3.6 The proposed activities and the potential impact pathways which are considered relevant to the EIA for the Project are as follows:

- i. **Construction phase:** the process involved in constructing the Project leading to the direct loss of intertidal and subtidal habitats under the footprint of the Lagoon, removal of sediment and a change in substrate depth through dredging (as part of the use of sediments for the seawall and temporary cofferdam and levelling in the vicinity of the turbine housing), or where works are undertaken in the approach channel of the River Neath or for the pontoon associated with the water shuttle in the approach channel of the River Tawe. Indirect effects may occur through localised changes to water flows, suspended sediment concentrations and smothering. Potential impacts may also arise through the introduction of non-native species and accidental spillages resulting in direct toxicity to marine ecology receptors.
- ii. **Operational phase:** the processes involved in operating and maintaining the Project over its lifetime. Potential impacts include the direct loss of intertidal and subtidal habitat under the footprint of the Lagoon (as identified for the construction phase) and introduction of a new hard surface (eg Lagoon seawalls, turbine and sluice gate structure), which will be available for colonisation. Indirect impacts include changes in water quality, habitat distribution and extent, habitat quality, and changes in the structure and function of biological assemblages. Potential impacts may also arise as a result of changes brought about by maintenance dredging requirements, through the spread and introduction of non-native species and damage/obstruction to planktonic species.
- iii. **Decommissioning:** the process of putting the Project into a non-operational state at the end of its operational lifetime. Impact pathways potentially include changes in water quality, habitat distribution and extent, habitat quality and changes in the structure and function of biological assemblages. It is equally likely that at the nominal end of the working life of this facility, the technology relating to power generation by tidal lagoons will have further developed, and the Project will have been progressively updated so that the Project could be kept in use as a generating station, and would not require decommissioning. If the Project's operation life is extended through ongoing updates, then the impacts would be the same as those

identified for the operational phase, subject to any improvements due to increased understanding and technological advances.

- 8.3.3.7 This ES proceeds on the basis of the outline construction programme as discussed in Chapter 4, Section 4.5.2, which anticipates construction starting in 2015 and with the main construction lasting for about three years. The assessments contained in this chapter are not materially sensitive to works commencing within the anticipated validity of the DCO, which is five years, or to an extension of (say) a further year-or-so.

Stage 2 - Understand change and sensitivity

- 8.3.3.8 The second stage involves understanding the nature of the environmental changes to provide a benchmark against which the changes and levels of exposure can be compared. The scale of the impacts via the impact pathways depends upon a range of factors, including the following:
- i. magnitude:
 - spatial extent (small/large scale);
 - duration (temporary/short/intermediate/long-term); and
 - frequency (routine/intermittent/occasional/rare);
 - ii. reversibility;
 - iii. probability of occurrence;
 - iv. the margins by which set values are exceeded (e.g. water quality standards);
 - v. the sensitivity of the receptor (resistance/adaptability/recoverability); and
 - vi. the baseline conditions of the system (including existing long-term trends and natural variability).

Stage 3 - Impact assessment

- 8.3.3.9 The likelihood of a feature being vulnerable to an impact pathway and the importance of a feature, based on its value and rarity, is then evaluated as a basis for assessing the level of the impact and its significance. Table 8.1 below outlines the importance of potential marine ecological receptors.

Table 8.1 Potential importance of ecological receptors (adapted from IEEM, 2006)

Level of Importance	Examples
International (Very High)	An internationally designated site or candidate site (SPA, pSPA, SAC, cSAC, pSAC ³ , Ramsar site, Biogenetic Reserve etc.) or an area which the country agency has determined meets the published selection criteria for such designation, irrespective of whether or not it has yet been notified. Internationally significant and viable areas of a habitat type listed in Annex 1 of the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). Regularly occurring, globally threatened species (i.e. IUCN Red listed) or species listed on Annex 1 of the Bern Convention (Draft Revised Annex I Of Resolution 6 (1998) of The Bern Convention). Regularly occurring populations of internationally important species that are rare or threatened in the UK or of uncertain conservation status. A regularly occurring, nationally significant population/number of any internationally important species.

³ SPA (Special Protection Area), pSPA (proposed Special Protection Area), SAC (Special Area of Conservation), cSAC (candidate Special Area of Conservation), pSAC (proposed Special Area of Conservation).

Level of Importance	Examples
National (High)	A nationally designated site (SSSI, NNR, MNR⁴) or a discrete area, which the country conservation agency has determined meets the published selection criteria for national designation (e.g. SSSI selection guidelines) irrespective of whether or not it has yet been notified. UKBAP habitats and species.
Regional/County (Moderate)	Viable areas of key habitat identified in the Regional/County BAP (Biodiversity Action Plan) or smaller areas of such habitat which are essential to maintain the viability of a larger whole. Viable areas of key habitat identified as being of Regional value. Any regularly occurring significant population listed in a Local Red Data Book. Significant populations of a regionally/county important species.
District/Borough (Low)	Areas of habitat identified in a sub-County (District/Borough) BAP or in the relevant Natural Area profile. District sites that the designating authority has determined meet the published ecological selection criteria for designation, including Local Nature Reserves selected on District/Borough ecological criteria (District sites, where they exist, will often have been identified in local plans). Sites/features that are scarce within the District/Borough or which appreciably enrich the District/Borough habitat resource.
Parish/Local (None)	Areas of habitat considered to appreciably enrich the habitat resource within the context of the Parish, e.g. species-rich hedgerows. No site designation. Species present are common and widespread.

N.B. Where species or habitats occur in more than one category above, the highest value is applied.

8.3.3.10 The key significance levels for either beneficial or adverse impacts are described as follows:

- insignificant:** insignificant change not having a discernible effect;
- minor:** effects tending to be discernible but tolerable;
- moderate:** where these changes are adverse they may require mitigation; and
- major:** effects are highest in magnitude and reflect the high vulnerability and importance of a receptor (e.g. to nature conservation). Where these changes are adverse they will require mitigation.

Impact assessment guidance tables

8.3.3.11 The matrices in Tables 8.2 to 8.4 are used to help assess significance.

8.3.3.12 Table 8.2 is used as a means of generating an estimate of exposure. Magnitude of change is considered in spatial and temporal terms (including duration, frequency and seasonality), and against the background environmental conditions in the study area. Once a magnitude has been assessed, this is combined with the probability of occurrence to arrive at an exposure score which is then used for the next step of the assessment, which is detailed in Table 8.3. For example, an impact pathway with a medium magnitude of change and a high probability of occurrence results in a medium exposure to change.

Table 8.2 Exposure to change, combining magnitude and probability of change

Probability of Occurrence	Magnitude of Change			
	Large	Medium	Small	Negligible
High	High	Medium	Low	Negligible
Medium	Medium	Medium/Low	Low /Negligible	Negligible
Low	Low	Low /Negligible	Negligible	Negligible
Negligible	Negligible	Negligible	Negligible	Negligible

⁴ SSSI (Site of Special Scientific Interest), NNR (National Nature Reserve), MNR (Marine Nature Reserve)

- 8.3.3.13 Table 8.3 is then used to score the vulnerability of the features of interest based on the sensitivity of those features and their exposure to a given change. Where the exposure and sensitivity characteristics overlap then vulnerability exists and an adverse effect may occur. For example, if the impact pathway previously assessed with a medium exposure to change acts on a receptor which has a high sensitivity, this results in a high vulnerability to change. Sensitivity can be described as the intolerance of a habitat, community or individual of a species to an environmental change and essentially considers the response characteristics of the feature. Thus, if a single or combination of environmental changes is likely to elicit a response then the feature under assessment will be considered to be sensitive. Where an exposure or change occurs for which the receptor is not sensitive, then the receptor will not be vulnerable. Similarly, where a negligible exposure is identified during an impact assessment, vulnerability will always be 'none' no matter how sensitive the feature is.

Table 8.3 Estimation of vulnerability based on sensitivity and exposure to change

Sensitivity of Feature	Exposure to Change			
	High	Medium	Low	Negligible
High	High	High	Moderate	None
Moderate	High	Moderate	Low	None
Low	Moderate	Low	Low	None
None	None	None	None	None

- 8.3.3.14 The vulnerability is then combined with the importance of the feature of interest using Table 8.4 to generate an initial level of significance. The importance of a feature is based on its value and rarity such as the levels of protection. For example, if a receptor has a high vulnerability and is considered to be a feature of low importance, the initial level of significance will be assessed as minor.

Table 8.4 Estimation of significance based on vulnerability and importance

Importance of Feature	Vulnerability of Feature to Impact			
	High	Moderate	Low	None
Very high	Major	Major	Moderate/Minor	Insignificant
High	Major	Moderate	Minor	Insignificant
Moderate	Moderate	Moderate/Minor	Minor/Insignificant	Insignificant
Low	Minor	Minor/Insignificant	Insignificant	Insignificant
None	Insignificant	Insignificant	Insignificant	Insignificant

Stage 4 - Impact management

- 8.3.3.15 The final stage identifies any impacts that have been found to have moderate and/or major adverse significance and which therefore require mitigation measures to reduce the impacts so that the residual impacts, as far as possible, are at acceptable levels. Within the assessment procedure, the use of mitigation measures alters the risk of exposure and hence requires significance to be re-assessed; thus the residual impact (i.e. with mitigation) is identified.

Stage 5 - Confidence assessment

- 8.3.3.16 Following the significance assessment, a confidence assessment is undertaken which recognises the degree of interpretation and expert judgement applied.

Cumulative impact and in-combination assessment

- 8.3.3.17 Cumulative effects are those that accrue over time and space from a number of developments. The effects of the Project are considered in conjunction with the potential effects from other plans, projects or activities that are both reasonably foreseeable in terms of delivery (e.g. have planning consent) and are located within a geographical scope where environmental impacts could act together to create a more (or less) significant overall effect.
- 8.3.3.18 The combination of predicted environmental impacts resulting from a single development on any one receptor that may collectively cause a greater (or lesser) effect is referred to as 'combined'. An example could be the combination of habitat loss, changes in water quality and introduction of non-native species impacting upon receptors together to cause a combined effect that is different to that assessed to occur when each impact is considered in isolation.
- 8.3.3.19 Where cumulative and combined effects are assessed to result in a different effect to that of their component parts, they may be described as:
- i. synergistic, whereby the interaction of two or more impacts results in a cumulative or combined effect that is greater than their individual component effects; or
 - ii. antagonistic, whereby the cumulative or combined effect is less than the component individual effects, for example as a result of different impacts acting to neutralise or counteract the effects of one another.
- 8.3.3.20 Cumulative impacts associated with the construction, operation and decommissioning of the Project with other plans, projects or activities are considered in Section 8.6. There is no standard prescriptive method for assessing cumulative and in-combination impacts and therefore the assessment is primarily based on professional judgement. Impacts are quantified where possible but where environmental assessment information regarding other plans, projects and activities is not available or uncertain, the assessment is necessarily qualitative.

8.4 Baseline conditions

8.4.1 Introduction

- 8.4.1.1 This section first includes a description of the nature conservation designations for the study area that provides a framework within which the statutory advisors for nature conservation will consider the Project. The ecological baseline is then characterised for plankton, macroalgae, intertidal and subtidal ecology and native oyster, collating information from available scientific literature, earlier impact studies and site specific surveys.

8.4.2 Nature conservation designations

Internationally designated sites

- 8.4.2.1 The Offshore Works Area does not overlap with any internationally designated or prospectively designated SAC, SPA or Ramsar sites. Within the Wider Study Area, the Crymlyn Bog SAC and Ramsar site is located approximately 1km from the Offshore Works (Figure 8.3, Volume 2). However, this is a terrestrial site and does not contain any marine features which should be considered within this chapter. Kenfig SAC is

located approximately 11.5km to the southeast of the Offshore Works Area in a southeast direction. This site is designated for terrestrial features, namely its internationally important sand dunes which support Fen Orchid. Crymlyn Bog and Kenfig SACs are discussed further in Chapter 12, Terrestrial Ecology.

- 8.4.2.2 The closest rMCZs are North of Lundy, Morte Platform and Bideford to Foreland Point, which have all been recommended as MCZs by the Finding Sanctuary Regional Steering Group on the English side of the Bristol Channel (Finding Sanctuary, 2011). However, these sites are all located over 35km away from the Project and none of these rMCZs was considered in the initial tranche of sites designated as MCZs in 2013.

Nationally designated sites

- 8.4.2.3 There are no SSSIs which directly overlap with the Offshore Works Area. However, the western extent of Crymlyn Burrows SSSI lies adjacent to the eastern Lagoon seawall. There are six SSSI sites within the Wider Study Area as shown in Figure 8.3, Volume 2. Although none of the SSSIs are designated for marine features, two SSSIs support birds which feed in intertidal areas and one of the SSSIs also supports species associated with the strandline (Table 8.5). These SSSIs are considered in greater depth in the Coastal Birds Chapter 11 and Terrestrial Ecology Chapter 12.

Table 8.5 Sites and features supported by nationally designated sites

Site Designation	Area (ha)	Distance from Project	Designated Interest Features
Blackpill SSSI	467	3km	Notified for its national importance as an over-wintering and passage site for waders, in particular Ringed Plover and Sanderling, but also for its local importance to Oystercatcher, Grey Plover, Bar-tailed Godwit, Knot and Dunlin.
Crymlyn Burrows SSSI	235	0.1km	Notified as one of the last sections of Swansea Bay largely unmodified by industrial development. Features include saltmarsh, sand dunes, rare plant species and strandline invertebrate assemblages.

Protected habitats and species

- 8.4.2.4 A number of UK BAP and nationally important habitats and species are found within Swansea Bay. These include biogenic reef forming species such as *Sabellaria alveolata*, hydroid rockpools, piddocks in clay with mussels, piddocks in peat with red algae, intertidal mudflats and sandflats, subtidal sands and gravels and the native oyster *Ostrea edulis*. Descriptions of where these protected species and habitats are found within the Wider Study Area are discussed in more detail within section 8.4.5 on intertidal ecology.

Sabellaria alveolata

- 8.4.2.5 *Sabellaria alveolata* is a gregarious segmented worm that builds tubes from sand or shell fragments. It is found intertidally (although occasionally subtidally) in exposed areas and is typically associated with the lower eulittoral and sub-littoral fringe rock and consolidated gravel/cobble substrata. The tubes are often densely aggregated forming a honeycomb pattern and may form large reefs up to several metres across and a metre deep (Jackson, 2008). *Sabellaria* reefs provide suitable 'crevices' for many infauna species to inhabit which would not otherwise be found in an area. For example, bryozoans, hydroids, molluscs, anemones, the pink shrimp and brittle stars. *Sabellaria*

alveolata reefs are a UK BAP habitat and are included in the list of habitats of principal importance for conservation of biological diversity in Wales under s42 of the NERC Act 2006.

Hydroid rockpools

- 8.4.2.6 This habitat is dominated by species able to withstand the frequent disturbance caused by wave action. The fact that rockpools are shallow and have a mixed substratum means that sand and pebbles will be frequently moved around the rockpool. This is especially true in stormy weather when larger cobbles and boulders may be moved into the pool and when the pool may be flushed clean of sediment. This in itself means that the community is unlikely to be a climax community, but more a transient community dominated by ephemeral, rapidly growing species that are able to quickly dominate space created by wave energy. Furthermore, both the flora and fauna are likely to vary both spatially, i.e. between rock pools, and on a temporal basis, depending on the frequency, severity and timing of disturbance (Marshall, 2005). Hydroid rockpools are considered nationally rare and if within a SAC are protected internationally as part of the Annex 1 Habitat Directive features; reefs, large shallow inlets and bays and estuaries. These features, however, are not internationally designated within Swansea Bay.

Piddocks

- 8.4.2.7 The common piddock, *Pholas dactylus*, is a boring bivalve, approximately elliptical in outline with a beaked anterior end, up to 12cm long. Piddocks bore into a wide range of substrata including peat and clay and are found from the lower shore to the shallow sublittoral (Hill, 2006). Piddocks may also represent an important food source for wildfowl and wading birds (Hill, 2006). Peat and clay exposures are afforded protection under the UK BAP Priority Habitat list and are included in the list of habitats of principal importance for conservation of biological diversity in Wales under s42 of the NERC Act 2006.

Intertidal mudflats and sandflats, subtidal sands and gravels

- 8.4.2.8 Intertidal mudflats and subtidal sands and gravels are protected as UK BAP Priority Habitats and are included in the list of habitats of principal importance for conservation of biological diversity in Wales under s42 of the NERC Act 2006. Intertidal mudflats are also included in the OSPAR list of threatened or declining habitats and species. Although intertidal mudflats and sandflats and subtidal sandbanks are listed in Annex 1 of the Habitats Directive, they are not internationally designated within Swansea Bay.

Native oyster

- 8.4.2.9 The native oyster, *Ostrea edulis*, is a bivalve mollusc that has an oval or pear-shaped shell with a rough, scaly surface. The two halves (valves) of the shell are different shapes. *Ostrea edulis* grows up to 11 cm long, rarely larger. The inner surfaces are pearly, white or bluish-grey, often with darker blue areas. *Ostrea edulis* is associated with highly productive estuarine and shallow coastal water habitats on firm bottoms of mud, rocks, muddy sand, muddy gravel with shells and hard silt (Jackson and Wilding, 2009). *Ostrea edulis* is a UK BAP species and is included, along with *Ostrea edulis* beds, in the OSPAR list of threatened or declining habitats and species as well as section 42 of

NERC 2006 as being "of principal importance for the purpose of conserving biodiversity in Wales."

Blue Mussel

- 8.4.2.10 The common or blue mussel, *Mytilus edulis*, is a bivalve mollusc common around the coast of the British Isles. The shell is inequilateral and roughly triangular in outline, however, shell shape varies considerably with environmental conditions. *M. edulis* usually grow to between 5 -10 cm although some populations never attain more than 2-3 cm, and the largest specimens may reach 15 -20 cm. *M. edulis* from the high intertidal to the shallow subtidal attached by fibrous byssus threads to suitable substrata. They are found on the rocky shores of open coasts attached to the rock surface and in crevices, and on rocks and piers in sheltered harbours and estuaries, often occurring as dense masses. *M. edulis* beds are a UK BAP habitat, are included in the list of habitats of principal importance for conservation of biological diversity in Wales under s42 of the NERC Act 2006 and are included in the OSPAR list of threatened or declining habitats and species.

8.4.3 Plankton

- 8.4.3.1 A review has been undertaken of available scientific papers on phytoplankton and zooplankton in Swansea Bay and the wider marine region (Bristol Channel). Significant phytoplankton growth can occur in Swansea Bay where areas of shallow water and less tidal dispersion, compared to the wider Bristol Channel, encourage growth (Joint, 1980). Joint reported patches of phytoplankton in Swansea Bay that were positively correlated to seawater temperature and negatively correlated with decreases in turbidity. It is hypothesised by Collins *et al.* (1979) that Swansea Bay has a tidal stream parallel to the Gower coast with an anti-clockwise eddy that results in partial separation of a water mass in the Bay from adjacent regions and allows for the development of discrete phytoplankton growth.
- 8.4.3.2 Phytoplankton surveys by APEM between November 2008 and October 2009 in the vicinity of the Hinkley Point C cooling water system found limited species diversity and abundance. A total of 21 species were found (19 diatoms, the flagellate *Ceratium furca* and the prasinophyte *Halosphaera viridis*). The highest phytoplankton abundance was found in July and consisted mostly of *Odontella* spp (Cefas, 2011a).
- 8.4.3.3 In terms of zooplankton, the Swansea Bay area can be broadly characterised by the presence of *Acartia bifilosa* (an estuarine and marine species). The temporary meroplankton (i.e. those that are planktonic for only part of their life cycle) includes localised blooms of invertebrate larvae such as crabs, molluscs, echinoderms and barnacles (Collins & Williams, 1981).
- 8.4.3.4 Throughout the Bristol Channel, the diversity of zooplankton was found to be relatively low, with a distribution that changes seasonally. Collins and Williams (1981) observed peaks in plankton biomass in July for the North Central Channel sub-region of the Bristol Channel which includes Swansea Bay.

8.4.4 Macroalgae

- 8.4.4.1 The zonation of intertidal algae found on the rocky shore within the Project area appears to follow general patterns found elsewhere; for example, *Pelvetia canaliculata*

and *Fucus spiralis* on the upper shore. The distribution of macroalgae within Swansea Bay is described further below within the results of the intertidal ecology survey (Section 8.4.5).

8.4.5 Intertidal ecology

- 8.4.5.1 Intertidal benthic ecology within the Bay has been well studied. In particular, CCW completed extensive mapping of the intertidal areas around Wales between 2001 and 2003. These maps provide a description of the habitats within and adjacent to the Project area as well as the Bay as a whole (Figures 8.4 and 8.5, Volume 2). The outputs from the CCW 2001-2003 survey have since been updated by a Phase 1 habitat survey undertaken in 2013, designed to ground truth the CCW biotope map for the area between the River Tawe and River Neath and checking for changes in biotope extent. This included updating biotope codes to match the latest 2004 versions of the “Marine Habitats Classification for Britain” naming convention (Connor *et al.*, 2004). Where relevant, the survey also looked to update any areas of change in the wider Bay. In particular, the survey looked to confirm the presence, distribution and condition of the *Sabellaria* reefs adjacent to the Tawe channel/Swansea Port entrance, and confirm the presence and distribution of any nationally important biotopes or rare species, including piddocks, hydroid rockpools, mudflats, sands and gravels and the native oyster *O. edulis*. The survey areas are shown in Figure 8.2 while Figure 8.6 (Volume 2) provides an overview of the biotopes recorded.
- 8.4.5.2 Although these survey results show broad comparisons in habitat extent between the two survey periods (2001-2003 and 2013), caution should be applied when interpreting the results as methodologies and data resolution (map scale and GPS accuracy) may vary between the two surveys.
- 8.4.5.3 In general, the intertidal coastal habitat of the Swansea Bay area is predominantly sand flats, with muddy to fine sandy sediments dominating.

Area between River Tawe and River Neath

- 8.4.5.4 Figures 8.7 to 8.9 (Volume 2) show the biotopes mapped between the River Tawe and River Neath during January 2013, and Table 1 of Appendix 8.2 (Volume 3) provides detail of the specific biotopes mapped, including additional notes and photographs.
- 8.4.5.5 The rock habitat running along the length of the upper shore of this area has changed little between the 2001-2003 survey and the 2013 survey. The upper limit of this rock habitat is dominated by lichens (corresponding to the biotopes LR.FLR.Lic.YG – yellow and grey lichens on supralittoral rock and LR.FLR.Lic.Ver.Ver – *Verrucaria maura* on very exposed to very sheltered upper littoral fringe rock) with the lower rock dominated by barnacles, limpets and other sea snails with occasional bands of seaweeds (LR.HLR.MusB.Sem.Sem - *Semibalanus balanoides*, *Patella vulgata* and *Littorina* spp. on exposed to moderately exposed or vertical sheltered eulittoral rock).
- 8.4.5.6 During the 2013 survey, at the far west of the rock wall close to the breakwater, two seaweed zones of *Pelvetia canaliculata* (channelled wrack seaweed) and *Fucus spiralis* (spiral wrack seaweed) were observed below the lichen dominated top shore (Figure 8.7, Volume 2). These correspond to the biotope codes LR.LLR.F.Pel – *Pelvetia canaliculata* on sheltered littoral fringe rock and LR.LLR.F.Fspi – *Fucus spiralis* on sheltered upper eulittoral rock, respectively. Zones of *Enteromorpha* and barnacle and

limpet zones occurred below this. These zones remain similar to that observed by CCW in 2001-2003. However, the *P. canaliculata* channel wrack seaweed was not previously recorded in the 2001-2003 survey as being present in this section of the rock wall.

- 8.4.5.7 Progressing east along the rock wall, both zones of seaweed extended for approximately 0.5km, before the rock habitat became dominated by lichens and barnacles and patches of the green seaweed *Enteromorpha* sp. (LR.FLR.Eph.Ent – *Enteromorpha* spp. on freshwater-influenced and/or unstable upper eulittoral rock) (Point B, Figure 8.8, Volume 2). The zoning and extent of these layers remained consistent and extended east for approximately 1.3km. This was again consistent with that observed in the 2001-2003 survey. However, during the 2013 survey small patches of mussels were present within the barnacles and limpet zone with very small patches of *Sabellaria* also present in the cracks in rocks above this area of mussels at Point D (Figure 8.8, Volume 2). These were not noted during the 2001-2003 survey. During the 2013 survey these areas were too small to map and this may have also been considered the case during the 2001-2003 survey. Periwinkles and beadlet anemones were also observed here in 2013.
- 8.4.5.8 Travelling further east along the rock wall, small zones of *P. canaliculata* and *F. spiralis* seaweeds were again present beneath the lichen zone, extending for approximately 0.6km along the rocky shore. These were also observed during the 2001-2003 survey (Point F, Figure 8.9, Volume 2).
- 8.4.5.9 In the far eastern section of the survey area shown on Figure 8.9, Volume 2, the lower rock is dominated by barnacles, limpets and patches of green algae (LR.HLR.MusB.Sem.Sem and LR.HLR.MusB.Cht.Cht). These habitats were also recorded during the 2001-2003 survey however they appear to have extended marginally to the east during the 2013 survey (Point G, Figure 8.9, Volume 2). Further west of Point G, clearly identifiable zones of *Enteromorpha* sp. (LR.FLR.Eph.Ent), *F. spiralis* (LR.LLR.F.Fspi) and barnacles and limpets (LR.HLR.MusB.Sem.Sem and LR.HLR.MusB.Cht.Cht) were observed below the lichen zone respectively, in zones consistent with those observed in 2001-2003.
- 8.4.5.10 In both the 2001-2003 and 2013 surveys, a variety of habitats were recorded throughout the lower intertidal with the majority focussed in the western corner of the survey area, including a number of nationally protected habitats and species (e.g. *S. alveolata* and hydroid rockpools).
- 8.4.5.11 The *S. alveolata* reef (LS.LBR.Sab.Salv – *Sabellaria alveolata* reefs on sand-abraded eulittoral rock) mapped in this area in 2013 follows much the same extent as that mapped in 2001-2003, particularly along the western, northern and eastern edges (Figure 8.7, Volume 2). However, the southern boundary of the *S. alveolata* reef does not currently extend as far down towards low water as that mapped in 2001-2003. A large band of mixed substrate with barnacles and limpets was also mapped by CCW between 2001 and 2003, extending from the breakwater through the middle of the *S. alveolata* reef. This band of mixed substrate (LR.FLR.Eph.BLitX – Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata) appears to have shifted south towards the low intertidal with *S. alveolata* forming a more consolidated, single reef where this habitat used to be. When comparing the area of *S. alveolata* reef mapped during the two surveys, CCW recorded 0.47km² in 2001-2003, whilst 0.63km² was recorded in 2013 within the same survey area.

- 8.4.5.12 A number of other species have also been recorded within the *S. alveolata* reefs during the 2013 survey. Of note is the presence of the invasive non-native American slipper limpet, *Crepidula fornicata*. In particular, large slipper limpet beds were observed in the south-east corner of the *S. alveolata* reefs. Some examples of single native oyster, whelk and whelk eggs, sponges and sea slugs were also recorded (see Table 1 in Appendix 8.2, Volume 3).
- 8.4.5.13 Consistent with the 2001-2003 survey, a number of hydroid rockpools (LR.FLR.Rkp.H - hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools) were observed in 2013 within the *S. alveolata* reef (Figure 8.7, Volume 2). Only the largest of these pools were mapped in 2013. However, it is important to note that there was standing water across the site during the 2013 survey. These pools are ephemeral and will change with different states of the tide, although the general distribution is similar to that observed in 2001-2003 with more pools recorded within the western section of the *S. alveolata* reef.
- 8.4.5.14 At the far west of the Wider Study Area, beneath the existing eastern Port breakwater, an area of mussel beds was recorded in 2001-2003. This mussel habitat was no longer present during the 2013 survey and instead has been replaced by mixed substrate with barnacles and limpets (LR.FLR.Eph.BLitX). Barnacles and sea snails were also commonly found on the breakwater of the River Tawe.
- 8.4.5.15 As observed during both the 2001-2003 and 2013 surveys, the remaining intertidal is composed of fine sand sediment (LS.LSa.FiSa.Po), extending from the River Neath to the eastern edge of the *Sabellaria* reef.
- 8.4.5.16 The area behind the existing eastern breakwater contains a small harbour. The sediments within the harbour consist predominantly of mud (LS.LMu.MEst.HedMac – *Hediste diversicolor* and *Macoma balthica* in littoral sandy mud) or mixed substrata (LR.FLR.Eph.BLitX). A small area north of the slipway consists of barren shingle (LS.LCS.Sh.BarSh – Barren littoral shingle) whilst south of the slipway medium to fine sand is dominant (LS.LSa.MoSa.AmSco – Amphipods and *Scolecopsis* spp. in littoral medium-fine sand). Lichen, *P. canaliculata* and *F. spiralis* are all present in zones from the top of the harbour wall, however, *Ascophyllum nodosum* (knotted-wrack) (LR.LLR.F.Asc.FS – *Ascophyllum nodosum* on full salinity mid eulittoral rock) dominates. Below this, a zone of barnacles and limpets is also present.

Area between Mumbles Head and River Tawe

- 8.4.5.17 Figures 8.10 to 8.11 (Volume 2) show the biotopes mapped west of the River Tawe during January 2013 and Table 2 of Appendix 8.2 (Volume 3) lists the specific biotopes mapped, including additional notes and photographs. This initial survey covered the area between the River Tawe westward to an area approximately in line with the A4216 (Sketty Lane). A subsequent survey in May 2013 covered the remaining intertidal area westward round to Mumbles Head (Figure 8.2, Volume 2). The biotopes mapped in May 2013 are shown on Figures 8.12 and 8.13 (Volume 2), and Table 3 of Appendix 8.2 (Volume 3) lists additional notes and photographs as well as the specific biotopes mapped.
- 8.4.5.18 Westwards from the River Tawe, the beach continues to be dominated by sand and muddy sand sediments. The 2001-2003 survey found that areas of *S. alveolata*,

piddocks and mussels were present in this area. However, the extent of each of these habitats changed considerably between the 2001-2003 and 2013 surveys.

- 8.4.5.19 The extensive areas of mussel beds observed in 2001-2003 were no longer present during the 2013 surveys. The mussel beds appear to have been replaced both by more extensive *S. alveolata* reefs (LS.LBR.Sab.Salv – *Sabellaria alveolata* reefs on sand-abraded eulittoral rock), particularly around the River Tawe. There were large areas of mixed substrate with dead mussel shells (LR.FLR.Eph.BLitX – Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata), across the entire sub-area, and mixed substrate with bladder wrack seaweed (LR.LLR.F.Fves.X – *Fucus vesiculosus* on mid eulittoral mixed substrata), particularly around Mumbles Head.
- 8.4.5.20 Small stretches of living mussel beds were observed at the very low intertidal area in similar locations to that observed in 2001-2003. However, these mussel beds generally occurred on and around mixed substrate which was littered with dead mussel shells and large beds of the invasive non-native species, American slipper limpet, *C. fornicata*. Slipper limpet competes for food and space with other filter-feeding species, and has been known to displace mussel beds (NNSS website; Rayment, 2008). It is possible that slipper limpet has out-competed mussels in these areas and that *S. alveolata* reefs have expanded into the vacated space. *S. alveolata* reefs were more prevalent in the north-western half of the area surveyed in January 2013, than in the south-eastern section around Mumbles Head, which was surveyed in May 2013 (Figures 8.10 to 8.11, Volume 2). The area of *S. alveolata* reef mapped during the January 2013 survey was 0.25 km², compared to 0.1 km² mapped in 2001-2003 within the same subdivision of the study area (N.B. caution should be applied when interpreting the results due to updates in GPS accuracy between the two survey periods). Although the *S. alveolata* reefs appear to have extended and replaced some areas of mussel beds since the 2001-2003 survey, the *S. alveolata* reefs were still observed in distinct patches during the 2013 surveys, rather than a wide-ranging single reef as observed on the eastern side of the River Tawe.
- 8.4.5.21 The CCW survey in 2001-2003 identified only a small number of areas of exposed clay with evidence of piddocks. The January and May 2013 surveys recorded more extensive and more numerous areas of exposed clay throughout the survey area. However, only the area surveyed in January 2013 showed clear evidence of burrowing piddocks (LR.MLR.MusF.MytPid – *Mytilus edulis* and piddocks on eulittoral firm clay). There was no evidence of piddocks in the clay habitat mapped further towards Mumbles Head in May 2013 (areas of exposed clay represented by 'C' on Figure 8.12, Volume 2). A number of exposed clay areas with burrowing piddocks were also identified in January 2013 which were too small to map. These are identified by a 'P' on Figures 8.10 and 8.11 (Volume 2).
- 8.4.5.22 Two areas of peat exposures with evidence of burrowing piddocks (LR.HLR.FR.RPid – *Ceramium* sp. and piddocks on eulittoral fossilised peat) were observed during both the January and May 2013 surveys at opposite ends of the Bay, along the top shore of the intertidal. Further areas of peat were also observed in the May 2013 survey which were too small to map. These are identified by 'Pt' on Figure 8.13 (Volume 2). The presence and extent of these piddock features may appear to vary throughout and between years due to the deposition of sandy sediment on top of the clay habitat in particular, making it harder to identify this habitat.

- 8.4.5.23 In the west, Mumbles Head is characterised by intertidal boulders and rock. The rocky headland foreshore is characterised by fucoids with occasional pockets of sand. The remaining intertidal consists of large expanses of muddy sandy shore.

Wider Swansea Bay

- 8.4.5.24 The CCW survey in 2001-2003 covered a more extensive area to the east of the River Neath than that mapped in the 2013 surveys. The biotopes found in this location in 2001-2003 are shown in Figure 8.5 (Volume 2). The sandy shore immediately to the east of the River Neath was backed by dune grassland and dense continuous saltmarsh, which are features of Crymlyn Burrows SSSI (see Table 8.5). Past the River Neath, the intertidal shore remains consistently sand up to and past the Port Talbot dock. The breakwaters surrounding Port Talbot provide diverse and complex substrata for a range of fauna to colonise. Barnacles, sea snails and mussels are commonly found there.

8.4.6 Subtidal ecology

- 8.4.6.1 The UKSeaMap subtidal habitat predictions provide an indication of the sediments likely to be present in the area and the species likely to be associated with them. In the vicinity of Swansea Bay, the sediments are best described as a mixture of circalittoral mud and sand (Figure 8.14, Volume 2) with the respective composition of each varying spatially. These predictions are broadly consistent with previous descriptions of the Bay which outline the dynamic nature of the area and the high tidal range. This, along with the curved shape of the Bay which results in varied exposure, gives a range of sediments grading from gravelly sand, through fine sand to sandy mud and muddy sand in the subtidal area.
- 8.4.6.2 Historically, there has been limited site-specific data relating to the subtidal benthic ecology within the Offshore Works Area and the Wider Study Area. Information on the subtidal ecology within Swansea Bay can be found in research undertaken by Shackley and Collins (1984). These studies confirmed that sediment type is important in determining species composition of the macrobenthic community within subtidal areas of the inner Swansea Bay. Shackley and Collins noted that the overall biodiversity of the Bay was low, which probably reflects the dominance of more mobile sandy and muddy substrates. They found that the bivalve *Spisula subtruncata* was strongly associated with sandy sediments whilst the polychaete *Nephtys hombergii* was found in higher numbers in muddier deposits. The success of bivalves in Swansea Bay, in particular *S. subtruncata*, has been attributed to their robust nature and their mobile epibenthic forms which enable them to survive rigorous treatment from strong currents (Warwick and George, 1980, cited in ABPmer, 2006). Gravelly sand supported a range of polychaetes including *N. hombergii*, *Cirriformia tentaculata* and *Aphelochaeta marioni*, the bivalve *Gari fervensis* and the amphipod crustaceans *Ampelisca spinipes* and *Urothoe elegans*.
- 8.4.6.3 In October 2010, CCW carried out survey work collecting video footage from 73 subtidal survey stations around Swansea Bay, including areas off Porthcawl (CCW, 2011). This project was originally designed to gather information on the status of historical and existing native oyster beds in Swansea Bay, but analysis of the video footage also provided basic seabed classification information at these sites. Figure 8.15 (Volume 2) shows the broad seabed types encountered at each station during the 2010 survey. The ground within Swansea Bay was mainly found to be mixed sand and cobble with

occasional boulder reef and areas of clean sand. Occasional areas of shell veneer over cobbles were also noted.

- 8.4.6.4 Figure 8.16 (Volume 2) provides a summary of the sediment data collected during the geophysical survey undertaken by Titan Environmental Surveys in 2012 (Titan, 2012). The results illustrate that the sediment composition in the Offshore Works area is relatively uniform grading gradually from sand to gravel with varying mixes of the two sediment types in between. The sediment composition within the Offshore Works area is discussed further in Chapter 6 Coastal Processes, Sediment Transport and Contamination.

Site specific benthic survey 2013

- 8.4.6.5 Due to the limited data relating to the subtidal ecology of Swansea Bay, Titan Environmental Surveys were commissioned to collect site specific data within the footprint and the area surrounding the Project to gain a better understanding of the subtidal benthic ecology. The scope and extent of the proposed survey work (Appendix 8.1, Volume 3) was discussed and agreed with Natural Resources Wales (NRW) through a meeting in December 2012 and correspondence in early 2013, and a licence for undertaking the works was obtained from the Marine Licensing Team of NRW (then the Marine Consents Unit) on 19 March 2013. As described in Section 8.3.2, Hamon grab samples were taken from 49 sites within the footprint of the Offshore Works as well as the Wider Study Area on 4-7 May 2013 (see Figure 8.17, Volume 2). In addition, seven epifauna/fish trawls were undertaken on 18 June 2013 to obtain qualitative samples of the epibenthos from across the area (Figure 8.17, Volume 2).

Grab samples

- 8.4.6.6 Figures 6.8 and 6.9 (Volume 2) in Chapter 6 Coastal Processes, Sediment Transport and Contamination shows the sediment distribution and spatial distribution of PSA results within and around the Lagoon. Within the Lagoon and to the west, the most dominant sediment type was sand and sandy gravel, with several sites, such as sites 29 and 30, being made up entirely of sand. In the wide area of the Lagoon, sediments were generally coarser with gravel making up a larger percentage of material; site 56 had the coarsest sediment. To the east of the Lagoon, near the mouth of the Neath Estuary some sites had more silt and mud present within samples, with the highest percentages of silt and mud being seen at site 40. Sediment composition of the area is discussed further in Chapter 6 Coastal Processes, Sediment Transport and Contamination.
- 8.4.6.7 A total of 282 taxa and 5,365 individuals were identified from all the benthic grab samples, with a total biomass of 19,384.3mg ash-free dry weight (AFDW) (Titan Environmental Surveys, 2013). The full taxonomic list, including the numerical abundance of each taxon by station, as well as the biomass (mg AFDW) of each major faunal group (by station) is included in Titan Environmental Surveys (2013).
- 8.4.6.8 The average number of individuals per sample was 109, the average number of taxa per sample 23, and the average biomass per sample 395.6mg AFDW. Annelida was the most abundant and most diverse major taxonomic group. This group also made the greatest contribution to total biomass sampled from across the area of interest. Crustacea contributed the second greatest to abundance, miscellaneous taxa (primarily comprised of Bryozoa, Ascidians, Sipunculids and small encrusting fauna) the second greatest to species diversity, and Mollusca the second greatest to total biomass.

- 8.4.6.9 The tube-dwelling polychaete *Pomatoceros lamarcki* was the most abundant species recorded, accounting for approximately 14% of all individuals. Other abundant taxa included the polychaete worms *Spiophanes bombyx*, *Sabellaria alveolata* and *Sabellaria spinulosa*, and the amphipod *Ampelisca diadema*. The most abundant mollusc was the bivalve *Abra alba*.
- 8.4.6.10 Greatest abundance was recorded at site 28 (within the centre of the Offshore Works Area as shown on Figure 8.17, Volume 2), where 424 individuals were recorded. Lowest abundance was recorded at site 4 (close to Mumbles Head) and site 30 (within the Lagoon), where just 2 individuals were recorded. The variable abundance recorded at sites 28 and 30 (which were located adjacent to each other within the Lagoon) can be attributed to the differences in sediment type recorded at these stations, with site 28 composed of gravelly sand and site 30 almost 100% sand. A maximum of 70 taxa was recorded at site 18 (composed of gravelly sand) located within the Lagoon, with just 1 taxon at sites 4 and 8 (both composed of sand) located around Mumbles Head.
- 8.4.6.11 Individuals of the gastropod mollusc *Ocenebra aciculata* which is described as 'Nationally Rare' were noted at sites 15 and 17 (both composed of gravelly sand) located within the Lagoon.
- 8.4.6.12 Individuals of non-native species were also identified from a number of samples. The barnacle *Elminius modestus* was the only non-native species recorded in relatively high numbers, with 97 individuals recorded at site 17 (located within the Lagoon). Lower numbers were also recorded at site 15 (inside the Lagoon) and site 1 (outside the Lagoon). The mud shrimp *Monocorophium sextonae*, the slipper limpet *Crepidula fornicata* and the soft-shelled clam *Mya arenaria* were also observed in low numbers (1-2 individuals). *M. sextonae* was recorded from site 1 and 9, located outside the Lagoon, whilst *C. fornicata* and *M. arenaria* were recorded from within the proposed Lagoon (from site 18 and sites 14, 15 and 48 respectively).
- 8.4.6.13 *Sabellaria* sp. was recorded in high abundance at several sites. One site in particular (site 29) recorded 376 individuals of *Sabellaria alveolata*, and likely constitutes an area of biogenic reef, although this cannot be verified from grab samples alone. However, this sample station was located within the proposed Lagoon, close to the area of intertidal *S. alveolata* surveyed during the intertidal survey in January 2013 (see Figure 8.6) and is most likely an extension of this reef into the shallow subtidal. It should be noted that *S. alveolata* reefs in the UK are predominantly recorded in the intertidal, however, the Severn Estuary and Bristol Channel are one of the few places where *S. alveolata* reefs occur extensively in the subtidal, as well as the intertidal (NE and CCW, 2009).
- 8.4.6.14 The composition of the biological communities in the survey area was analysed using multivariate methods. These methods take into account the species variety and the relative abundance of each taxon recorded at each station and allow some inferences to be made relating to the characterising species that comprise the major communities in the survey area.
- 8.4.6.15 The similarity between infauna recorded from each of the sampling sites was low. Samples acquired from across Swansea Bay were representative of a total of 6 infaunal groups, as shown in Figure 8.18 (Volume 2) and described below.

- 8.4.6.16 Assemblage type A was the most commonly occurring and most diverse group. This assemblage was identified from 19 sites collected from across the area, both within the Lagoon and to the west of the site around Mumbles Head. Sediments from all sites were composed of gravelly sand. Characterising fauna of this group included the polychaete worms *Pomatoceros lamarcki*, *Sabellaria spinulosa*, *Cirriformia tentaculata*, *Jasmineira elegans*, the bivalve *Sphenia binghami* and the amphipod *Ampelisca diadema*.
- 8.4.6.17 Assemblage type B comprised 11 sites across Swansea Bay, within the eastern half of the Lagoon and outside the Lagoon around Port Talbot. These sites consisted of sandier sediments, with small proportions of gravel and silt/mud, and constituted 10 taxa (at the 90% cut-off for low species contribution). Characterising taxa for fauna of this group included the polychaete worms *Spiophanes bombyx*, *Owenia fusiformis*, *Nephtys hombergii*, the bivalve *Nucula nitidosa* and individuals belonging to the Phylum *Nemertea*.
- 8.4.6.18 Assemblage type C comprised 5 sites all outside the Lagoon consisting of predominantly sand sediment. At the 90% cut-off for low species contribution, 6 taxa were identified from these sites. The polychaete worms *Magelona johnstoni*, *Nephtys*, *Glycera tridactyla*, *Magelona filiformis*, *Magelona mirabilis* and the bivalve *Nucula nitidosa* were key characterising fauna of this group.
- 8.4.6.19 Assemblage type D occurred at 3 sites across the Wider Study Area, comprised of sandy sediment. This group was characterised by the presence of one individual, the polychaete worm *Travisia forbesii*.
- 8.4.6.20 Assemblage type E was the least commonly occurring group, being found at only two sites across the study area comprising almost 100% sand. This was not a diverse group with the amphipod *Urothoe brevicornis* being the only species present and therefore accounting for 100% of this group's similarity.
- 8.4.6.21 Assemblage type F comprised 4 sites across the Swansea Bay area. Characterising fauna of this group included the polychaete worms *Nephtys cirrosa*, *Nephtys* (juv), *Chaetozone christiei* and *Owenia fusiformis*.
- 8.4.6.22 As observed by Shackley and Collins (1984) the geographical distribution of these faunal groups reflects differences in sediment composition across the survey area. Assemblage type A was characteristic of gravelly sand sediment whilst assemblage type B was characteristic of sand sediment with higher percentages of silt/mud and assemblage types C, D, E and F were characteristic of sandier sediments.

Trawl samples

- 8.4.6.23 Across all survey sites the most dominant species present were the netted dog whelk *Hinia reticulata* (representing 33% of total individuals) and the brittlestar *Ophiura ophiura* (30% of total individuals). Other abundant species included the sea gooseberry *Pleurobrachia pileus* (12% of total individuals), the hermit crab *Pagurus bernhardus* (8% of total individuals) and the bivalve mollusc *Abra alba* (7% of total individuals) (Titan Environmental Surveys, 2013). The sea gooseberry *P. pileus* is a pelagic species and it is likely that the notably high numbers observed during the survey were trapped in the net during hauling. The species could potentially affect the epibenthos since it preys on zooplankton, it may also be a source of food for benthic species and juvenile fish.

- 8.4.6.24 Several colonial species were recorded during the survey which could not be meaningfully counted and were thus recorded as present (1) or absent (0). The species were: *Nemertesia ramosa*, *Alcyonium digitatum*, *Hydrallmania falcata*, *Tubularia indivisa*, *Dysidea fragilis*, *Alcyonidium diaphanum*, *Flustra foliacea* and *Botryllus schlosseri*.
- 8.4.6.25 The most dominant commercial species recorded during the trawl were the common whelk *Buccinum undatum*, common sole *Solea solea* and the brown shrimp *Crangon crangon*.
- 8.4.6.26 The most abundant and diverse trawl survey was Transect T6 located outside of the Lagoon near Port Talbot (1710 individuals and 25 taxa). Over 75% of this trawl sample comprised two species; the dog whelk *H. reticulata* and the brittlestar *O. ophiura*.
- 8.4.6.27 Trawl sites T2 and T3, located within the Lagoon, recorded the lowest abundance and diversity (14 individuals and 5 taxa; and 13 individuals and 10 taxa, respectively). The low species diversity observed at T2 meant that the trawl was repeated in order to ensure that malfunctioning of the sampling equipment was not responsible for the relatively poor sample. The second haul did not produce a markedly different sample and it was thus concluded that the original beam trawl produced a representative sample of the fauna present at the site.

Wider Study Area

- 8.4.6.28 A number of studies have been undertaken in the Wider Study Area, specifically around Port Talbot (ABP Research and Consultancy, 1996; United Utilities, 2003; ABPmer, 2010). These studies found the benthic community in the Port Talbot area to be low in diversity but typical of similar habitats in Swansea Bay and Bristol Channel as a whole. The benthic community in the Port Talbot area is relatively impoverished compared to other estuarine systems in the UK. This has been largely attributed to the high natural suspended sediment loads, mobility of sediment and tidal currents.

1996 Port Talbot Capital Dredge ES (Survey undertaken 9 September 1995)

- 8.4.6.29 For the 1996 Port Talbot Capital Dredge ES, a benthic survey of the area in and around the Port Talbot navigational channel was undertaken on 9 September 1995 (ABP Research & Consultancy, 1996). Some variation in assemblage was observed with the change in sediment type, with the poorly-sorted, muddy sand having lower species diversity and richness compared to gravelly sands. Polychaetes were the dominant group in both sediment types characterised by *Nephtys* species and *Notomastus lamarcki*. There were also significant numbers of the bivalves *S. subtruncata* and *Nucula nucleus*. Crustacean fauna was relatively sparse and dominated by the brown shrimp, *Crangon crangon* and cumacean *Diastylis rathkei typica*; the amphipod *Corophium arenarium* was also abundant.

United Utilities 2003 survey

- 8.4.6.30 A survey of benthic fauna, covering the middle of Swansea Bay and south towards Scarweather sands, was undertaken by United Utilities in 2003. The survey reported similar community structures to that found in the 1996 Port Talbot Capital Dredge survey with patterns of faunal abundance clearly related to sediment characteristics. The faunal community in the sands was of low diversity, dominated by the polychaetes

Nephtys cirrosa and *Ophelia borealis*, and the mysid *Gastrosaccus spinifer*. Sediments along the proposed wind farm cable route towards Margam Sands graded to poorly-sorted muddy sands with high organic content. Again, species diversity was low but no species tended to dominate.

- 8.4.6.31 Towards the north of Scarweather Sands, in the middle of Swansea Bay, a range of sediment types were reported with organic contents that increased with decreasing sediment size. Poorly sorted gravelly sand, with an average organic content, had the highest species diversity and richness of all the sites. Poorly-sorted, muddy sand had lower species diversity and richness compared to gravelly sands but community structure was very similar. Polychaetes were the dominant group in both sediment types characterised by *Nephtys* species and *N. lamarcki*. However, abundances were low for the majority of species.
- 8.4.6.32 The cumacean *D. rathkei typica* was the dominant species in sandy mud and muddy sites. Species diversity and richness were the lowest in muddy sites dominated by the polychaete *Nephtys kersivalensis* and the bivalves *Abra nitida* and *Nucula nitidosa*.

2010 Port Talbot proposed channel deepening environmental appraisal

- 8.4.6.33 A site specific benthic survey was undertaken around Port Talbot on 22-23 July 2010 for the proposed channel deepening environmental appraisal (ABPmer, 2010). Annelida were the dominant phylum, representing 40% of all species sampled. There is broad correspondence between the 1995 and the 2010 benthic grab data with the most prevalent biotope being SS.Ssa.ImuSa.SsubNhom *S. subtruncata* and *N. hombergii* in shallow, muddy sand, albeit the species assemblage had diversified over the 15 year time gap. Again there was clear differentiation between the muddier and sandier sediments, with the sandier sediments hosting a range of amphipod species that were best described by the biotope, SS.Ssa.IfisSa.TbAmPo, semi-permanent tube-building amphipods and polychaetes in sublittoral sand.

HABMAP

- 8.4.6.34 The HABMAP project aimed to predict seabed habitats across the southern area of the Irish Sea and north-eastern part of the adjoining Celtic Sea. The predictive modelling did not extend as far as Swansea Bay. However, there were two data points located within Swansea Bay that were surveyed as part of the HABMAP project. These data points are positioned offshore from the Project, slightly off centre and to the west, in an approximate alignment with Port Talbot Dock and Mumbles Head. These correspond to the biotopes SS.Ssa.IfisSa.ScupHyd – *Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles and SS.SCS.ICS.Slan – dense *Janice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand respectively.

Native oysters

- 8.4.6.35 Historically, oyster beds appear to have been quite extensive within Swansea Bay, with the main focus around Mumbles (Oystermouth). However, with over-fishing in the late 1800's and pollution in the Bay the oyster industry began to decline. This was

exacerbated in the 1920's when a blood parasite affected the native oyster and most of the beds were wiped out⁵.

- 8.4.6.36 Since that time, a study was undertaken to investigate the distribution and abundance of native oysters at locations thought to support them (CCW, 2003). Within Swansea Bay two locations were looked at, namely East of Mumbles Head and Outer Green Grounds (which is further offshore of the East Mumbles site). During these diver surveys, suitable habitat was found at Outer Green Grounds to support this species, but no native oysters were found. The report stated "Although no *Ostrea edulis* was found at this site the mix of substrate and current conditions suggest that it may be present, albeit at low density, based on historic occurrence."
- 8.4.6.37 In September 2011 the majority of Swansea Bay was identified under EU Regulation 854/2004 as Class B for oyster (see Chapter 7 Marine Water Quality). In the past, three boats have dredged for native oysters in Swansea Bay. These have fished less than 1 tonne in each of the last 10 years (Phil Coates, Welsh Government, pers. comm., cited in Cefas, 2011b). It has been suggested that now only one commercial operator dredges for native oyster in the Bay (Bill Arnold, pers. comm.; cited in Cefas, 2011b). However, in September 2012, the Swansea Bay Port Health Authority reported that, although small numbers of oyster can be found in the area, there are no commercial oyster operations currently in the Bay.
- 8.4.6.38 CCW completed a further survey of Swansea Bay in 2010 to gather information on the status of historical and existing native oyster beds (CCW, 2011). A number of locations were looked at including White Oyster Ledge, Mumbles, Swansea Bay (Fairway Beds) and Porthcawl. Analysis of video footage provided basic seabed classification and recorded other factors relevant to oyster ecology including any presence of slipper limpets (*Crepidula fornicata*) and silt deposition. Live oysters and 'possible' live oysters were recorded at 18 survey stations. Dead oyster shells, as single or occasional shells, were widely distributed and present at 46 survey stations and aggregations of oyster shells at 12 survey stations. *Crepidula fornicata* were present at 8 stations. In 2012 a further survey on stock assessment of native oysters across Swansea Bay showed that only a few large old individuals remained in the Bay. Out of all the shells collected in over 100 dredge tows only 2 spat were found on any of them (Mumbles Oyster Company, 2013).
- 8.4.6.39 Two single live oyster shells were recorded during the intertidal biotope survey undertaken in 2013, indicating the presence of native oyster within the Bay, but not the extent of their distribution. However, no oysters were observed during the 2013 subtidal surveys across the Bay.
- 8.4.6.40 As discussed in Section 8.8, a licence was granted in September 2013 to the Mumbles Oyster Company Ltd to lay 10,000 young oysters on a 70 acre historic oyster bed within Swansea Bay. TLSB is also exploring options to enhance native oyster habitat within Swansea Bay as part of the Project in conjunction with SEACAMS⁶. This work should also

⁵ http://www.welshwales.co.uk/oyster_harvesting.htm

⁶ SEACAMS, a project part-funded by the European Regional Development Fund through the Welsh Government is a partnership between Bangor, Swansea and Aberystwyth Universities. SEACAMS aim is to integrate research and business opportunities in the marine sector in Wales.

assist the Swansea Bay Local Fisheries Action Group⁷ achieve some of the objectives within its main themes, namely:

- i. theme 1: strengthening competitiveness of local fisheries;
- ii. theme 2: restructuring and redirection of economic activities;
- iii. theme 3: diversification activities including creation of additional jobs outside the fisheries sector; and
- iv. theme 4: adding value to fisheries products.

8.4.7 Baseline summary

8.4.7.1 A summary of the extent and condition of the habitats and species found within the surveyed intertidal area of Swansea Bay in 2013 is provided in Table 8.6. Large, well structured reefs of *S. alveolata* were found within the Offshore Works Area (between the Rivers Tawe and Neath) bordered by mixed substrate and large expanses of sand flats. The rocky shore backing this area displayed typical zonation patterns. To the west of the River Tawe, sand flats dominate with distinct areas of *S. alveolata* reef, piddock habitat and mixed substrate present. Two small areas of live mussel beds were observed on the low intertidal. In the wider Swansea Bay area extensive mud and sand flats extend down to Mumbles head and east of the River Neath down to Port Talbot.

Table 8.6 Summary of the extent and condition of the habitats and species found within the surveyed intertidal area of Swansea Bay in 2013

Location	Feature	Extent	Condition
Footprint of Offshore Lagoon works – between River Tawe and River Neath (Jan 2013)	<i>Sabellaria alveolata</i>	0.63 km ²	Extensive well structured reefs supporting a number of species including whelk, sponges, periwinkles, sea slug and slipper limpet.
	Hydroid rockpools	0.02 km ²	Small standing pools present throughout the <i>Sabellaria alveolata</i> habitat.
	Rocky shore	2.8 km (length)	Well established bands of (from top to bottom of rocky shore) lichens, barnacle and limpets, green <i>Enteromorpha</i> algae, <i>Pelvetia canaliculata</i> and <i>Fucus spiralis</i> seaweeds.
	Sand	1.86 km ²	Wide flat area of sand habitat.
	Mixed substrate	0.14 km ²	Mixed substrate with barnacles and periwinkles present at western and south western boundary with <i>Sabellaria alveolata</i> reef. Boundary often not well defined between the two habitats.
Harbour outside River Tawe breakwater (Jan 2013)	Harbour wall	0.5 km (length)	Lichens, <i>Pelvetia canaliculata</i> and <i>Fucus spiralis</i> seaweeds, barnacle and limpets all present but <i>Ascophyllum nodosum</i> dominates.
	Mud	0.01 km ²	Mud habitat interspersed with areas of clearly defined mixed substrate.
	Mixed substrate	0.01 km ²	Mixed substrate interspersed with areas of clearly defined mud habitat.
Surveyed area west of River Tawe (Jan 2013)	<i>Sabellaria alveolata</i>	0.26 km ²	Distinct areas of reef were mapped with large expanses of sand between reefs.
	Piddocks	0.05 km ²	Areas of exposed clay and peat present. No live piddocks found but evidence of burrowing piddocks observed.

⁷ <http://www.swansea.gov.uk/index.cfm?articleid=48756>

Location	Feature	Extent	Condition
	Mixed substrate	0.33 km ²	Distinct areas of mixed substrate between areas of sand. Substrate often littered with dead mussel shells.
	Mussels	0.01 km ²	Two small distinct patches observed on low intertidal, often mixed with large beds of slipper limpet and mixed substrate, as well as dead mussel shells.
Surveyed area north of Mumbles Head (May 2013)	<i>Sabellaria alveolata</i>	>0.01 km ²	One small area of <i>S. alveolata</i> on mixed substrate of boulders and cobbles. Not as extensive as other areas mapped.
	Peat exposures with piddocks	0.01 km ²	One area of peat outcrop with evidence of piddocks.
	Mixed substrate with barnacles and periwinkles	0.31 km ²	Distinct areas of mixed substrate between areas of sand. Substrate often littered with dead mussel shells and slipper limpets.
	Mixed substrate with bladder wrack	0.13 km ²	Distinct areas of mixed substrate with bladder wrack seaweed.
	Mussels	0.02 km ²	Two small distinct patches observed on low intertidal.

8.4.7.2 A summary of the subtidal ecology of Swansea Bay is provided in Table 8.7 below. There was considerable variation in abundance and diversity of benthic invertebrate species recorded across Swansea Bay in 2013, with sediment type the dominant factor in determining species composition of the subtidal areas of Swansea Bay. In general, more mobile areas of finer sand or mud tend to be of lower species abundance and diversity, whereas gravelly sand and cobbles support a higher diversity and abundance. Taxa belonging to the Phylum Annelida were generally found to dominate the benthic communities in terms of abundance, species diversity and total biomass. Several stations recorded high numbers of *Sabellaria* sp., with highest abundance recorded close to the mapped intertidal *S. alveolata* adjacent to the River Tawe.

Table 8.7 Overview of habitats and species found within the subtidal area of Swansea Bay

Location	Sediment	Species
Offshore Works Area (Titan 2013 Surveys)	Gravelly sand	Polychaete worms <i>Pomatoceros lamarcki</i> , <i>Sabellaria spinulosa</i> , <i>Cirriformia tentaculata</i> , <i>Jasmineira elegans</i> , the bivalve <i>Sphenia binghami</i> and the amphipod <i>Ampelisca diadema</i> .
	Sand	Polychaete worms <i>Spiophanes bombyx</i> , <i>Owenia fusiformis</i> , <i>Nephtys hombergii</i> , the bivalve <i>Nucula nitidosa</i> and individuals belonging to the Phylum <i>Nemertea</i> .
Offshore Works Area (Shackley and Collins, 1984)	Gravelly sand	Polychaete worms - <i>Nephtys hombergii</i> , <i>Cirriformia tentaculata</i> and <i>Aphelocheata marioni</i> , bivalve molluscs (e.g. <i>Gari fervensis</i>) and amphipod crustacea (e.g. <i>Ampelisca spinipes</i> and <i>Urothoe elegans</i>).
	Sand	Bivalve molluscs, e.g. <i>Spisula subtruncata</i> and polychaete worms.
Off Mumbles Head (HABMAP data)	Sand and mixed gravelly sand	SS.SCS.ICS.SLan - dense <i>Lanice conchilega</i> and other polychaetes.
Central Bay (HABMAP data)	Sand with cobbles or pebbles	SS.SSa.IFiSa.ScupHyd - <i>Sertularia cupressina</i> and <i>Hydrallmania falcata</i> in tide-swept sublittoral area.
Swansea Bay and south towards Scarweather sands (United Utilities, 2003)	Sands	Low diversity, dominated by the polychaetes <i>Nephtys cirrosa</i> and <i>Ophelia borealis</i> , and the mysid <i>Gastrosaccus spinifer</i> .
	Poorly-sorted muddy sands	Low abundance and diversity, sediment characterised by <i>Nephtys</i> species and <i>Notomastus lamarcki</i> .
	Poorly sorted gravelly sand	Slightly higher abundance and diversity than muddy sands - characterised by <i>Nephtys</i> species and <i>N. Lamarck</i> .
	Sandy mud and muddy sites	Cumacean <i>D. rathkei</i> typical.

Port Talbot (ABP Research and Consultancy, 1996)	Poorly-sorted, muddy sand and gravelly sands	Polychaetes worms - dominant e.g. <i>Nephtys</i> species and <i>Notomastus lamarcki</i> . Bivalves – abundant e.g. <i>S. subtruncata</i> and <i>Nucula nucleus</i> . Crustacean fauna - relatively sparse - the brown shrimp, <i>Crangon crangon</i> and cumacean <i>Diastylis rathkei</i> dominant. Amphipod <i>Corophium arenarium</i> also abundant.
Port Talbot dredged channel area (ABPmer, 2010)	Muddy sand	Bivalves - <i>S. subtruncata</i> and Polychaete - <i>N. hombergii</i>
	Sandier sediments	Range of amphipod species (biotope, SS.SSa.IFiSa.TbAmPo - semi-permanent tube-building amphipods and polychaetes in sublittoral sand).

8.5 Likely significant effects

8.5.1 Introduction

8.5.1.1 This section considers the potential changes to the baseline conditions, which may be brought about by the Project. A number of potential pathways exist by which the Project could affect the distribution, extent and/or quality of intertidal and subtidal ecology during the construction, operational and decommissioning phases. The individual key impact pathways have been identified and allocated into the short term construction phase and longer-term operational phase effects. In some cases (e.g. habitat extent), the potential impact pathways (both negative and positive) will start in the construction phase, but the full extent will only be realised in the operation phase. As such, these impact pathways have been discussed under the longer-term impacts in the operational phase. The full list of relevant pathways is as follows:

8.5.1.2 Construction phase

- i. Impact Pathway 1: Changes in suspended sediment concentrations.
- ii. Impact Pathway 2: Release of contaminants associated with the dispersion of suspended sediments.
- iii. Impact Pathway 3: Re-deposition of suspended sediment.
- iv. Impact Pathway 4: Discharges and accidental spillages.
- v. Impact Pathway 5: Introduction of non-native species.
- vi. Impact Pathway 6: Changes in habitat suitability.

8.5.1.3 Operational phase:

- vii. Impact Pathway 7: Change in habitat extent.
- viii. Impact Pathway 8: Changes in habitat suitability.
- ix. Impact Pathway 9: Changes in water quality.
- x. Impact Pathway 10: Changes in suspended sediment concentrations.
- xi. Impact Pathway 11: Damage/obstruction to planktonic species.
- xii. Impact Pathway 12: Changes in the structure and function of biological assemblages as a result of changes in biological interactions.
- xiii. Impact Pathway 13: Introduction of non-native species.

- 8.5.1.4 For each pathway, the impact assessment has been structured according to the key receptors (i.e. Plankton, Macroalgae, Intertidal ecology and Subtidal ecology). The assessment has also taken account of the proposed phasing of construction based on the results of the coastal processes assessment (see Coastal Processes Chapter 6).
- 8.5.1.5 Two options for the future/decommissioning have been considered and the potential decommissioning phase effects are discussed in more detail below in Section 8.5.15.
- 8.5.1.6 None of the plankton or macroalgae species identified as part of the baseline study are protected under local, national or international legislation. Furthermore, given the widespread nature of plankton and the fact that the macroalgae species occurring in Swansea Bay are typical of the wider region, the assessment for these receptors has considered that as a worst case, their overall level of importance is low, according to the EIA methodology described in Table 8.1.
- 8.5.1.7 A number of UK BAP and nationally important intertidal and subtidal habitats and species are found within Swansea Bay as a whole (Section 8.4.2). Within the intertidal ecology and subtidal ecology impact assessments, both protected and unprotected habitats and species have been assessed for each impact pathway (where applicable) so that their relative importance in terms of level of protection is recognised. Overall the importance of these receptors is considered to range from low for unprotected features to high for nationally protected features, such as Sabellaria alveolata. The importance of these nationally protected features as high reflects the fact that although these habitats are protected they are not internationally designated within Swansea Bay (see Section 8.4.2).

8.5.2 **Impact Pathway 1: Changes in suspended sediment concentrations (SSC) during construction**

General scientific context

- 8.5.2.1 Elevated levels of suspended sediment (increased turbidity) during construction works can cause a reduction in light penetration through the water column, restricting the light availability for photosynthesis in primary producers such as phytoplankton, periphyton and macrophytes. Such primary producers are important sources of food and oxygen and a reduction in their productivity and growth rates can reduce the diffusion of waste products and water quality (Chapman and Fletcher, 2002). Increased siltation may also cover some of the frond surfaces of macroalgae species reducing photosynthesis and growth rates.
- 8.5.2.2 Changes in suspended sediment concentrations (SSC) can lead to changes in the intertidal and subtidal sand communities through changes in sediment availability. A reduction in the amount of sediment carried in suspension will reduce the amount of sediment available to intertidal and subtidal habitats (e.g. sandflats and sandbanks). Conversely increases in suspended sediment will increase the amount of sediment available to intertidal and subtidal communities. These changes may alter the composition of the biological assemblage associated with these receptors.

Project impact assessment

- 8.5.2.3 The design of the Geotubes® to retain sediment and the presence of relatively coarse sediments in the vicinity of the temporary cofferdam (for the construction of the

turbine and sluice gate housing) will limit the potential for increased SSC to impact on receptors.

- 8.5.2.4 The coastal processes modelling predicts that sediments mobilised during the capital dredging and Lagoon seawall construction works will be widely dispersed across Swansea Bay (see Chapter 6). However, these changes are relatively short lived with increases in SSC dissipating to background concentrations within a spring-neap tidal cycle on cessation of the works. Overall, when compared against background SSC, the magnitude of change is considered to be small on the scale of Swansea Bay and medium in close proximity to the dredge and fill works. Changes outside of Swansea Bay are unlikely to be distinguished from natural variability and are therefore considered to be negligible. The probability of occurrence of changes in SSC during dredging and Lagoon seawall construction will be high and as such, the overall exposure to change is considered to be low at the Swansea Bay scale, medium local to the works in Swansea Bay and negligible in the Bristol Channel.
- 8.5.2.5 In terms of the dispersion of dredged sediments deposited at the Swansea (Outer) licensed disposal ground (LU130), the sediment dispersion will be largely confined to the Inner Bristol Channel, although extending in an east to west direction towards the shoreline between Kenfig Burrows and Porthcawl (Coastal Processes Chapter 6). Temporary short duration peaks in SSC may reach circa 3,500 mg/l in relatively close proximity to the deposit ground for short periods of time (minutes). General increases in SSC, however, are typically below 500 mg/l, falling rapidly to less than 10 mg/l over slack periods when sedimentation occurs. In close proximity to the shoreline, maximum increases in SSC at any given time are predominantly below 10 mg/l, which is well within the background SSC found in the Bay (see Chapter 6). All increases in SSC within the water column will quickly revert to background levels following completion of the disposal operations in less than two spring-neap tidal cycles. The magnitude of change during disposal is considered to be medium due to the spatial extent of the plume. The probability of occurrence is high and therefore the exposure to change will be medium.

Plankton

- 8.5.2.6 Background levels of suspended sediment are naturally high in the Bristol Channel and within Swansea Bay (Coastal Processes Chapter 6) and plankton are already tolerant to existing changes in the sediment regime (e.g. during natural storm events, maintenance dredging activities in navigation channels and deposit of sediments at the licensed disposal ground). The sensitivity of this receptor is therefore considered to be low, giving rise to at worst a low vulnerability. The importance of plankton is considered to be low given that they are widespread and not afforded any protection and therefore the overall significance of changes in SSC during capital dredging, seawall and temporary cofferdam construction and disposal operations is considered to be **insignificant**.

Macroalgae

- 8.5.2.7 The species of macroalgae occurring in Swansea Bay, *P. canaliculata* and *F. spiralis*, have both been described as having no sensitivity and low sensitivity respectively to increases in suspended sediment (White, 2008; Marshall, 2005). Macroalgae species would only be affected by increased suspended sediment whilst they are immersed in water, when light levels would be reduced, affecting photosynthesis. However, both *P. canaliculata* and *F. spiralis* have been estimated to spend up to 90% of their time out of

the water, where photosynthesis can still take place effectively in air. Therefore, although the overall exposure to change is considered to be medium in Swansea Bay and negligible in the Bristol Channel, the duration of any exposure to increases in SSC would only be minimal. In addition, upon return to normal SSC levels, photosynthesis rates would be quickly restored and the growth rate would return to normal levels (White, 2008; Marshall, 2005).

- 8.5.2.8 As described above, Swansea Bay has naturally high levels of suspended sediments and therefore it can be assumed that the macroalgae present would be tolerant of such conditions. The sensitivity of this receptor is therefore considered to be at worst low, giving rise to at worst a low vulnerability. The importance of macroalgae is considered to be low given that they exhibit typical zonation patterns on the rocky shore found elsewhere in the UK and are not afforded any specific level of protection. The overall significance of changes in SSC during capital dredging, seawall and temporary cofferdam construction works is therefore considered to be **insignificant**.
- 8.5.2.9 This receptor will not be impacted by changes in SSC brought about during the disposal of dredged material at the Swansea (Outer) licensed disposal ground (LU130).

Intertidal ecology

- 8.5.2.10 In terms of the intertidal sandflat and muddy to fine sandy sediments that dominate in Swansea Bay, changes in SSC may interfere with the feeding apparatus of the fauna present in the sediments that are suspension feeders (e.g. polychaetes), and potentially result in a decreased total ingestion and growth rate. This habitat already experiences and is tolerant of a variable sedimentary regime with periods of accretion and erosion (Chapter 6, Coastal Processes). Furthermore, recovery of fauna is very rapid and therefore this habitat is not considered to be sensitive to changes in SSC.
- 8.5.2.11 Tube building polychaetes are likely to be tolerant of increases in SSC as they usually inhabit waters with high levels of suspended sediment which they actively fix in the process of tube making. Although suspension feeders rely on suspended sediment to feed, they are likely to be less tolerant of large increases in suspended sediment as their feeding structures may become clogged, compromising growth (Rayment, 2002; Riley and Ballerstedt, 2005; Ager, 2009; Jackson and Hiscock, 2008). In Swansea Bay, *Sabellaria alveolata* depend on suspended sediment supply to support tube growth and reef-building, and therefore while an increase in suspended sediment may facilitate tube building, it may also clog up their feeding apparatus (Jackson, 2008).
- 8.5.2.12 The common piddock *Pholas dactylus* produces sediment in the process of burrow drilling so is likely to be tolerant of increased suspended sediment (Hill, 2006). The blue mussel *Mytilus edulis* is also relatively tolerant of increased suspended sediment, possessing efficient shell cleaning and pseudofaeces expulsion mechanisms to remove silt (although it should be noted that pseudofaeces production involves an energetic burden) (Tyler-Walters, 2008).
- 8.5.2.13 Increased suspended sediment has the potential to clog the feeding apparatus of the suspension feeding community of hydroid rockpools, resulting in reduced ingestion and, subsequently, a decrease in growth rate. For hydroids especially this could potentially lead to a reduction in overall biomass. Moreover, because rockpools have a 'pulsed' influx of water, the suspended sediment may settle between tides and increase the depth of sediment in the pool. Some smaller immobile species including barnacle and

tubeworms may be temporarily smothered (Marshall, 2005). Although there may be a reduction in the overall hydroid standing biomass, this will not affect the recognizable biotope (Marshall, 2005). Furthermore, hydroids exhibit remarkable powers of regeneration and recovery is likely to be immediate. Overall therefore this habitat is not considered to be sensitive to changes in SSC.

- 8.5.2.14 Based on the above review, the overall sensitivity of this receptor is considered to be at worst low, giving rise to at most a low vulnerability. The importance of intertidal ecology is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in SSC during capital dredging, Lagoon seawall construction works and disposal activities is therefore considered to range from **insignificant to minor adverse** significant.

Subtidal ecology

- 8.5.2.15 As noted in Chapter 6 Coastal Processes, Swansea Bay has relatively high and variable background levels of suspended sediment, indicating that the existing subtidal communities can already tolerate these concentrations and are unlikely to be sensitive to changes brought about by the Project during capital dredging, construction of the Lagoon seawall or dredge disposal activities.
- 8.5.2.16 The only protected species known to occur in the subtidal environment in Swansea Bay is the native oyster *Ostrea edulis* (see Sections 8.4.6.35 to 8.4.6.40). Native oysters reject unwanted particles and respond to an increase in suspended sediment by increasing pseudofaeces production with occasional rapid closure of their valves to expel accumulated silt (Yonge, 1960, cited in Jackson and Wilding, 2009) both of which exert an energetic cost. Suspended sediment has been shown to reduce the growth rate of adult oysters, through increased shell deposition and an inability to feed efficiently. Filtration has been reported to be completely inhibited by 10 mg/l of particulate organic matter and significantly reduced by 5 mg/l (Hutchinson & Hawkins, 1992; cited in Jackson and Wilding, 2009). *Ostrea edulis* larvae survived 7 days exposure to up to 4000 mg/l silt with little mortality. However, their growth was impaired at 750 mg/l or above (Moore, 1977). Changes in SSC brought about during the capital dredging and Lagoon seawall construction is only likely to result in temporary sub-lethal effects and based on the available scientific evidence, their overall sensitivity is considered to be low.
- 8.5.2.17 The overall sensitivity of the subtidal ecology receptor is considered to be at worst low, giving rise to at most a low vulnerability. The importance of subtidal ecology is considered to range from low for unprotected features to high for protected features, including subtidal sands and gravels, and the native oyster *O. edulis*. The overall significance of changes in SSC during capital dredging, Lagoon seawall construction works and disposal activities is therefore considered to range from **insignificant to minor adverse** significant.

Confidence

- 8.5.2.18 There is a degree of uncertainty associated with any hydrodynamic and sediment modelling predictions. Within this assessment uncertainty has been expressed by presenting changes and exposures as ranges rather than single point values, wherever possible. Furthermore, a worst case judgement has been followed in order to ensure that the assessment is conservative and precautionary. In terms of impacts associated with changes in SSC on marine ecology receptors, these are well understood through a

large number of research studies on this subject. Therefore the overall confidence in the assessment of this pathway is considered to range from medium to high.

8.5.3 Impact Pathway 2: Release of contaminants associated with the dispersion of suspended sediments during construction

General scientific context

- 8.5.3.1 The resuspension of sediment as a result of areas being excavated or disturbed during construction works can lead to the release and mobilisation of sediment-bound contaminants into the water column. These include both toxic contaminants, such as heavy metals, pesticides and hydrocarbons, and non-toxic contaminants, such as nutrients. The chemical contaminants associated with sediments can be removed or disturbed during construction and may be dispersed, redistributed and deposited elsewhere in the marine environment where they may become available for uptake by marine organisms. Over the longer-term any such releases could also become stored in the surface sediments of benthic habitats for future benthic uptake.
- 8.5.3.2 When found in sufficient quantities, chemical contaminants can potentially induce functional and structural changes on planktonic plants (phytoplankton) and animals (zooplankton) by stimulating or inhibiting growth (Lafabrie *et al.*, 2013; Walsh, 1978). Subsequent changes in trophic diversity can cause a shift in community function with potential implications for ecosystem processes such as material cycling, nutrient generation and decomposition (Diaz and Schaffner, 1990). Since they are grazed upon by many animals, the plankton are an important link in the transfer and accumulation of pollutants from water to higher trophic levels (Walsh, 1978).
- 8.5.3.3 Macroalgae are considered sensitive to toxic contamination where concentrations exceed sensitivity thresholds. Adult furoid algae accumulate heavy metals and are generally fairly robust in the face of chemical pollution. However, germlings appear to be intolerant of heavy metal pollution. Copper was found to retard the growth rate of *Fucus spiralis* sporelings at concentrations greater than 5.8 µg/l and caused permanent damage in sporelings exposed to concentrations of 12.24 µg/l for 10 days. The species has been observed to readily recruit to cleared areas so recovery rates are expected to be high (White, 2008; Marshall, 2005).
- 8.5.3.4 High levels of chemical contaminants can potentially cause genetic, reproductive and morphological disorders in marine species. Contaminants may also have combined effects. Sub-lethal effects of chemical contamination on marine invertebrates can reduce the fitness of individual species. Suspension-feeding organisms may be particularly vulnerable to pollutants in the water column due to their dependence on filtration. There is evidence to support links between chemical pollution and such disorders (MacDonald and Ingersoll, 2010). Studies have suggested links between contamination with polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), amines and metals and a range of disorders. Also, increased incidence of tumours, neoplasia, DNA damage, polyploidy, hypoploidy, hermaphroditism and reduced immune response have all been reported in marine invertebrates in areas of high levels of pollution (Hannam *et al.*, 2010; Catalano *et al.*, 2012; Hesselman *et al.*, 1988; Nacci and Jackim, 1989; Gardner *et al.*, 1992; Schaeffer, 1993; Barsiene, 1994).
- 8.5.3.5 Although no specific information on the sensitivity of *S. alveolata* has been found in the scientific literature, the habitat forms part of the SAC habitat 1170 Reefs which has

been assessed as having low sensitivity to heavy metal contamination (Scottish Executive, 2007).

- 8.5.3.6 Mercury is considered to be the most toxic metal to bivalve molluscs, including piddocks, with mortalities occurring above 0.1-1 µg/l after 4-14 days exposure (Crompton, 1997 cited in Hill, 2006). Copper, cadmium, zinc, lead, arsenic and chromium can also be problematic (with copper being the most toxic to bivalves and chromium the least toxic). The embryonic and larval stages of bivalves are the most intolerant of heavy metals. The common piddock spawns for several months every year, so when normal levels of contamination resume rapid recolonisation by the pelagic larvae is likely (Hill, 2006). Similarly the blue mussel *M. edulis* is relatively tolerant of heavy metal contamination and can recover rapidly once contamination levels are returned to normal through good annual recruitment (Tyler-Walters, 2008).
- 8.5.3.7 Evidence suggests that hydroids may suffer at least sublethal effects and possibly morphological changes and reduced growth due to heavy metal contamination (Marshall, 2005). Adult gastropod molluscs were also considered to be tolerant of heavy-metal toxicity, whilst winkles may absorb metals from the surrounding water by absorption across the gills or from the diet, and evidence from experimental studies on *Littorina littorea* suggest that the diet is the most important source. The lethal dose of mercury (as mercury chloride) for this species is between 1 and 10 ppm of seawater (Staines, 1996, cited in Marshall, 2005). This stems mainly from its ability to accumulate trace elements and compounds and consequential behavioural changes. Despite the characterising species showing primarily sublethal effects, the nature of hydroid rockpools, especially those higher up on the shore, may mean that contamination takes some time to be flushed from the biotope.
- 8.5.3.8 Although contaminants may accumulate in the tissues of oysters, which may be harmful for human consumption, the adults themselves are considered to be tolerant of high levels of heavy metal contamination. However, larval stages of oysters may be more intolerant, impairing recruitment and resulting in a reduction in the population over time (Jackson and Wilding, 2009).
- 8.5.3.9 Lethal effects may allow a shift in community composition to one dominated by pollution-tolerant species such as oligochaete worms (Elliott *et al.* 1998). A reduction in community species richness is associated with elevated levels of pollutants. Contamination with PAHs, for example, leads to high levels of mortality in amphipod and shrimp species, and decreased benthic diversity (Long *et al.*, 1995). Similar reductions in diversity are linked with heavy metal contamination (Dauvin, 2008). Polychaete worms are thought to be quite tolerant of heavy metal contamination, whereas crustaceans and bivalves are considered to be intolerant (Rayment, 2002).

Project impact assessment

- 8.5.3.10 The proposed capital dredging and construction works have the potential to remobilise contaminants that may be trapped within the sediments. The likelihood of mobilising sediments and contaminated sediments and the magnitude of any effect is dependent upon the level of contamination; the proximity of the activity to the feature; the type of activity occurring; the manner in which that activity is pursued (including the extent and duration); the particle size of the disturbed sediments (contaminants tend to be associated with finer particles) and the hydrodynamic conditions.

8.5.3.11 Based upon the sediment contaminant analysis results discussed in the Coastal Processes Chapter (Chapter 6) and the Project Description Chapter (Chapter 4), no analysed sediment sample across the Lagoon footprint exceeded Cefas Action Level 2 for any specific contaminant. Based on the coastal processes assessment, the risk of contamination through these proposed works to other areas of Swansea Bay (or the Bristol Channel) is considered to be insignificant. In addition the design of the Geotubes® to retain sediment and the presence of relatively coarse sediments in the vicinity of the temporary cofferdam will limit the potential for increased suspended sediment concentrations to impact on receptors.

8.5.3.12 For the purposes of intertidal and subtidal receptors, the overall magnitude of change is considered to be negligible to small, and the probability of occurrence is low given the low level of contamination in the samples. The exposure to change will therefore be negligible.

Plankton

8.5.3.13 Plankton are not vulnerable to a negligible change in exposure as a result of the potential release of contaminants associated with the dispersion of suspended sediments during construction activities. The overall impact to this receptor is therefore considered to be **insignificant**.

Macroalgae

8.5.3.14 Macroalgae are not vulnerable to a negligible change in exposure. The overall impact to this receptor is therefore considered to be **insignificant**.

Intertidal ecology

8.5.3.15 Intertidal ecology is not vulnerable to a negligible change in exposure. The overall impact to this receptor is therefore considered to be **insignificant**.

Subtidal ecology

8.5.3.16 Subtidal ecology is not vulnerable to a negligible change in exposure. The overall impact to this receptor is therefore considered to be **insignificant**.

Confidence

8.5.3.17 The overall confidence in the assessment of this pathway is considered to be medium to high, as the assessment is based on the analysis of sediment samples from the field and the potential impacts from the release of contaminants on marine ecology receptors are well understood, through a large amount of scientific evidence on this subject.

8.5.4 Impact Pathway 3: Re-deposition of suspended sediment during construction

General scientific context

8.5.4.1 The re-deposition of suspended sediment has the potential to cause the smothering of intertidal and subtidal benthic habitats and species. This smothering has the potential to lower the percentage of light and thus reduce photosynthesis and growth rates of primary producers.

- 8.5.4.2 Microphytobenthos live, grow and are consumed in the top few millimetres of shallow water marine habitats. Phytoplankton and microphytobenthos use light energy to fix carbon dioxide into organic matter and are limited to the upper few mm of oxygenated sediments as light only penetrates the sediment to a depth of 2-3mm (Macintyre *et al.*, 1996). Smothering, therefore, has the potential to reduce photosynthesis and lower growth rates. However, recovery is expected to be high given that these organisms can rapidly colonise on newly settled sediment. Microphytobenthos provide a major energy source to the higher trophic levels in marine ecosystems, especially food webs connected to intertidal mudflats. Changes to microphytobenthos will alter the food supply available to deposit feeders and the associated potential effects are discussed in the appropriate receptor assessments below.
- 8.5.4.3 The extent that smothering might affect macroalgae species depends on the state of the tide during or immediately after the smothering event. If smothering occurs while the plant is immersed in water and the tide was able to disperse sediment immediately away then some or all of the plant would escape burial allowing macroalgae to continue photosynthesising (White, 2008; Marshall, 2005).
- 8.5.4.4 In general, the rate of recovery is dependent upon just how stable and diverse the assemblage was in the first place. A regularly disturbed sedimentary habitat with a low diversity benthic assemblage is likely to recover more quickly (i.e. return to its disturbed or 'environmentally-stressed' baseline condition) than a stable habitat with a pre-existing mature and diverse assemblage. Bolam, Whomersley and Schratzberger (2004), for instance, concluded that the relatively rapid recovery which they observed (at a location in the Crouch Estuary) was due to the opportunistic nature of the invertebrate assemblages and the dispersive behaviour of the dominant species that were there before the materials was placed over them. Furthermore, in cases where the quantity and type of sediment deposited does not differ greatly from natural sedimentation, e.g. of similar particle size, the effects are likely to be relatively small as many of the species are capable of migrating up through the deposited sediments (Budd, 2004).
- 8.5.4.5 A key consideration when seeking to understand the effects of sedimentation and recovery is that the quantitative extent of habitats and their qualitative character are subject to natural variability against which any change must be assessed (although, inherently, the quantitative changes are more readily measured and easily defined and measured than qualitative changes). This is because the latter exhibits more complex spatial and temporal variation complex in response to physical changes, but a range of other variable abiotic factors (tidal flows, wave regime, salinity, climate, natural suspended sediment changes etc.) and biological changes (species colonisation, predation mortality etc.).

Project impact assessment

- 8.5.4.6 The coastal processes modelling predicts that the maximum amount of sedimentation during the capital dredging and Lagoon seawall construction works will occur within the immediate vicinity of the works (see Figure 6.19, 6.21, 6.24 and 6.26 (Volume 2)). Most of the sediments that settle within the dredging area will be re-dredged as part of the works. Very small (millimetric) changes in maximum sediment are predicted to occur in the wider area comprising the sediment plume extent. These changes are predominantly short term with the majority of sediment being remobilised on subsequent tides.

8.5.4.7 Overall, therefore, the maximum magnitude of change is considered to be medium within the immediate vicinity of the works reducing to low in the wider area where changes are predicted within Swansea Bay. Changes outside of Swansea Bay are unlikely to be distinguished from natural variability and are therefore considered to be negligible. The probability of occurrence of changes in sedimentation during dredging and Lagoon seawall construction will be high and as such, the overall exposure to change is considered to be low to medium in Swansea Bay and negligible in the Bristol Channel.

8.5.4.8 In terms of the dredged sediments deposited at the Swansea (Outer) licensed disposal ground (LU130), the coastal processes assessment predicts that maximum sedimentation across the extent of the sediment plume will principally occur within and in close vicinity to the deposit ground. On the subsequent flood/ebb tide when flow speeds are sufficient, these sediments are once again re-suspended into the water column and undergo further dispersion. With time, these dispersed sediments migrate further away from the source (i.e. the deposit site) towards the outer extent of the predicted plume, with maximum concentrations decreasing with distance. The overall magnitude of change during disposal is considered to be low to medium. The probability of occurrence is high and therefore the exposure to change will be low to medium.

Plankton

8.5.4.9 Phytoplankton and microphytobenthos present within Swansea Bay and Inner Bristol Channel are considered to be well adapted to natural levels of siltation due to the existing dynamic conditions and shifting sediment regime. The sensitivity of this receptor is therefore considered to be low, giving rise to at worst a low vulnerability. The importance of plankton is considered to be low and therefore the overall significance of re-deposition of sediment during capital dredging, Lagoon seawall construction and disposal operations is considered to be **insignificant**.

Macroalgae

8.5.4.10 Macroalgae species in vicinity of the dredging and Lagoon seawall construction activities are considered to have a low sensitivity to changes in sedimentation. This is because they will only be exposed while they are submerged in water and the tide will rapidly re-mobilise and disperse sediment, which will allow the macroalgae to continue to photosynthesise. The vulnerability of this receptor is therefore at most low and their importance is considered to be low. The overall significance of re-deposition of sediment during capital dredging and Lagoon seawall construction works is therefore considered to be **insignificant**.

8.5.4.11 This receptor will not be impacted by changes in sedimentation brought about during the disposal of dredged material at the Swansea (Outer) licensed disposal ground (LU130).

Intertidal ecology

8.5.4.12 Intertidal sandflats are considered to be moderately sensitive to the deposition of 5cm of fine material in a single event and to have high sensitivity to the deposition of 30cm of fine material in a single event (Tillin *et al.*, 2010). The sensitivity assessments

available on the MarLIN⁸ website indicate that clean sandy shores have a low sensitivity to smothering as although the deposition of 5cm of sediment would cover the tubes of amphipods and prevent suspension feeding they are considered able to burrow through the sediment and recover almost immediately (Budd, 2006; Rayment, 2002).

- 8.5.4.13 *Sabellaria alveolata* depend on suspended sediment supply to support tube growth and reef-building. An increase in siltation may facilitate tube building, however, it may also clog up feeding apparatus. *S. alveolata* have been known to survive short-term burial for days or even weeks, although feeding and growth will be curtailed. *S. alveolata* would be expected to recover almost immediately once conditions return to normal and feeding is able to recommence (Jackson, 2008).
- 8.5.4.14 Piddocks are expected to be tolerant to smothering because their feeding apparatus can be cleared of particles, although this will cost energy. Experimental work with common piddock *P. dactylus* showed that large particles can either be rejected immediately in the pseudofaeces or passed very quickly through the gut (Knight, 1984, cited in Hill, 2006). During field surveys *P. dactylus* were found covered in a layer of sand in Aberystwyth and Exmouth and in Eastbourne individuals were found living under a layer of sand with siphons protruding at the surface (Hill, 2006; Marshall, 2008).
- 8.5.4.15 Burial of *M. edulis* beds by large-scale movements of sand, and resultant mortalities have been reported from Morecambe Bay, the Cumbrian Coast and Solway Firth (Holt *et al.*, 1998, cited in Tyler-Walters, 2008). However, although apparently sedentary, *M. edulis* is able to move some distance to change its position on the shore or within a bed or to resurface when buried by sand. Young mussels in particular have been reported to move upwards when buried by sediment becoming lightly attached to each other, but many are also suffocated (Dare, 1976, cited in Tyler-Walters, 2008). *M. edulis* are able to discharge sand rapidly from the mantle cavity within the first 15 minutes of burial with an exponential decrease over the next 4 hrs and slow discharge over 48 hrs. *M. edulis* were found to have died after an average of 13 days exposure to ca. 1200 mg/l suspended sediment (mud) but survived the length of the experiment (duration unstated but >25 days) at 440 mg/l (Tyler-Walters, 2008).
- 8.5.4.16 Intertidal species and habitats present within Swansea Bay are considered to be well adapted to natural levels of siltation due to the existing dynamic conditions. Although the predicted scale of maximum changes in bed thickness are 25mm (0.25cm) (i.e. well below the 5cm moderate sensitivity threshold described above (Tillin *et al.*, 2010)) and these sediments are likely to be re-dredged for use within the Lagoon wall as part of the works, the overall sensitivity of the intertidal ecology receptor is considered to be at worst moderate within close proximity (approximately 100m) to the capital dredging activities given that the type of sediment that will be re-deposited will be of a slightly finer composition than that which already occurs. The sensitivity of this receptor is considered to reduce to low in the wider area (greater than 100m from the capital dredging areas) given that maximum changes in sedimentation will be millimetric, and species are likely to be able to easily burrow through the sediment and rapidly recover from any change. The overall vulnerability of this receptor will be moderate within close proximity to the construction works and low in the wider area of the sediment plume. The importance of intertidal ecology ranges from low to high depending on the level of protection afforded to features. The overall significance of the re-deposition of sediment during capital dredging and seawall construction is therefore considered to be

⁸ <http://www.marlin.ac.uk/habitatsensitivityranking.php>

insignificant to minor adverse significant for unprotected features. In terms of nationally protected features in close proximity to the capital dredging activities, including *Sabellaria* reef and intertidal mudflats and sandflats⁹, the impact will be **moderate adverse significant**. With increasing distance from the dredging works, the impact will reduce to **minor adverse significant** for protected features in the wider area where changes are predicted, including *Sabellaria* reef and intertidal mudflats and sandflats.

- 8.5.4.17 The moderate adverse impact is specifically associated with the *Sabellaria* reef and intertidal mudflats and sandflats located in close vicinity to the proposed construction works. Given the short-lived and temporary nature of the smothering effects during capital dredging, these features are expected to recover almost immediately once conditions return to normal. The long-term direct loss of these habitats as a result of the Lagoon itself, have been specifically assessed in Sections 8.5.8 and 8.5.9. Mitigation measures that have been proposed for these losses are discussed further in Section 8.7. These include the translocation of the *Sabellaria* reef and opportunities to encourage the settlement of *Sabellaria* larvae. Concepts such as “Bioblocks”¹⁰ and rock pools are also proposed to be designed into the Lagoon wall with the aim of promoting and enhancing ecological diversity and in turn providing a biodiversity offsetting measure for any losses (see Section 8.8). The residual impact to these protected features is considered to be of **minor adverse** significance with the incorporation of the in-built offsetting measures. As identified in Section 8.7, the proposed translocation mitigation for *Sabellaria* is not proven, but it is being implemented to optimise the potential for colonisation of the habitat created as a result of the Project, as well as for the benefit of enhancing scientific knowledge. Although factors affect the effectiveness of the outcome, and consequentially effect the confidence placed in the mitigation, it remains important to implement such measures. For the biodiversity offsetting measures, there is currently no formal guidance on the relative value of different habitats. However, the artificial rocky reef is expected to have a higher ecological value than the relatively depauperate intertidal habitat and therefore, although the change in residual impact is uncertain due to the unproven method proposed for *Sabellaria* translocation, it has been moderated to recognise the potential benefits of these measures. In addition, the extent and quality of protected intertidal habitat features will be monitored to determine the actual effects of the Project during operation and enable the results of the impact assessment to be validated (Section 8.7 and Chapter 23).
- 8.5.4.18 Due to this distance offshore of the Swansea (Outer) licensed disposal ground (LU130), intertidal habitats and species will not be impacted by changes in sedimentation brought about during the disposal of dredged material at this site.

⁹ Intertidal mudflats and sandflats have been referenced here as they are a grouped feature under Annex 1 of the Habitats Directive; 1140 Mudflats and sandflats not covered by seawater at low tide. However, it is important to note that no intertidal mudflat was found during the baseline surveys of Swansea Bay and thus only intertidal sandflats will be impacted.

¹⁰ The Bioblock is a cuboid construction with approximate dimensions 1.5 x 1.5 x 1 m and modifications on 5 sides. The block includes pools of variable depths on the upper surface, multiple depth holes on 2 opposing vertical surfaces and horizontal grooves on the remaining surfaces

Subtidal ecology

- 8.5.4.19 Subtidal species and habitats present within Swansea Bay, including subtidal sands and gravels, are considered to be well adapted to natural levels of siltation due to the existing dynamic conditions. Although the type of sediment re-deposited as a result of construction activities will be of a slightly finer composition, the quantity outside of the immediate vicinity of the works will be millimetric and of a similar scale to natural sedimentation.
- 8.5.4.20 Oysters are not very tolerant to smothering, with up to 5cm of sediment preventing the flow of water that permits respiration, feeding and removal of waste. Populations of *Ostrea edulis* have been reported to die out due to smothering of oyster beds by sediment and debris from the land after flooding during exceptionally high tides. Even small increases in sediment deposition have been found to reduce growth rates in *O. edulis* (Yonge, 1960; Grant *et al.*, 1990; both cited in Jackson and Wilding, 2009).
- 8.5.4.21 The overall sensitivity of oysters to deposition of sediment during dredging and disposal activities is therefore considered to be high. Given that there are unlikely to be any oysters in the area where sedimentation is predicted to occur (Chapter 6 Coastal Processes), the overall vulnerability of this receptor is considered to be negligible. Despite the high importance of *O. edulis*, the overall significance of the re-deposition of sediment during capital dredging, Lagoon seawall construction works and disposal activities is therefore considered to be **insignificant**. Based on the above scientific review, the overall sensitivity of the remaining subtidal habitat is considered to be low. Given the high level of protection (UK BAP) afforded to subtidal sands and gravels, the overall significance of the impact on this receptor is considered to be **minor adverse**.

Confidence

- 8.5.4.22 Uncertainty is inherent in any physical processes modelling prediction. Within this assessment uncertainty has been expressed by presenting changes and exposures as ranges rather than single point values, wherever possible. Furthermore, a worst case judgement has been followed in order to ensure that the assessment is conservative and precautionary. Impacts from changes in sedimentation on marine ecology receptors are well understood through a large body of scientific research. Therefore the overall confidence in the assessment of this pathway is considered to range from medium to high.

8.5.5 Impact Pathway 4: Discharges and accidental spillages during construction

General scientific context

- 8.5.5.1 The potential for chemical contaminants (associated with runoff, stored material or spillages) released accidentally into the local marine environment exists during any construction works. Plankton, macroalgae, intertidal and subtidal habitats and species are sensitive to toxic contamination (where concentrations of contaminants exceed sensitivity thresholds) as a result of the release of synthetic contaminants such as fuels, oils and construction material during all stages of construction work. In particular, there is a risk that any uncontrolled releases of materials or sediments into the water column could make contaminants temporarily available for uptake by marine organisms. Over the longer-term any such releases could also become stored in the surface sediments of benthic habitats for future benthic uptake.

- 8.5.5.2 Such adverse effects on water and sediment quality could arise from spillage of oils/fluids from construction vessels and machinery or from any materials used or stored on site. Oil spills can result in large-scale damage to intertidal and subtidal communities, degrading infaunal communities and changing predator-prey interactions. Reductions in abundance, biomass and production of the fine sand community was very evident after the Amoco Cadiz oil spill, through the disappearance of the dominant populations of the amphipods *Ampelisca* sp., with large numbers of dead polychaetes and other fauna also being washed up following the spill. This major oil spill occurred in 1978 and after 2 weeks, the level of hydrocarbons in subtidal sediments reached 200 ppm (Dauvin, 1984; cited in Rayment, 2002).
- 8.5.5.3 Subtidal sediments are generally at less risk from oil spills than intertidal sediments, unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil in to the sediment (Elliott *et al.*, 1998). Oil smothers the sediments preventing oxygen exchange, thereby producing anoxia and leading to the death of infauna. Stranded oil is not readily removed in sheltered conditions and penetrates the sediment, especially sands, due to wave and tidal action and destabilises it. The microbial degradation of the oil increases the biological oxygen demand and produces anoxic conditions. Often the low oxygen environment in sediments will mean that the bacterial degradation takes some time so that the oil remains toxic (Tyler-Walters and Marshall, 2006; Budd, 2004; Rayment, 2002).
- 8.5.5.4 The potential impacts that chemical contaminants in sediment can have on plankton, macroalgae, intertidal and subtidal receptors, when found in sufficient quantities in the marine environment, have been reviewed in Section 8.5.3.

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- 8.5.5.5 An element of risk inherently exists that accidents or spillages could occur during the construction works that would result in releases into the marine environment with potential effects on water and sediment quality and thus marine ecology receptors. There is the potential for fuel spillages and contamination arising from accident/collisions of vessels delivering rock or other construction materials to the Port of Swansea or from vessels carrying out construction work.
- 8.5.5.6 Vessels already navigate through Swansea Bay, in and out of the Port of Swansea (see Chapter 14, Navigation and Marine Transport). Existing marine and traffic management procedures are in place to prevent (where possible) and mitigate for potential navigational hazards from on-going commercial operations at the Port of Swansea. Further mitigation measures are discussed specifically for the Project in Chapter 14: Navigation. All vessels related to construction will work within these requirements.
- 8.5.5.7 The magnitude of any spillage event is likely to vary from small to large depending upon the scale of the pollution that occurs. However, given that any risk of spillages from materials stored on site is low because construction materials brought to site will be uncontaminated (e.g. quarried rock armouring) and potentially contaminating substances will be stored appropriately away from the marine environment (See Section 8.7), the probability of an accidental spillage event occurring is predicted to be low. Therefore, the exposure is considered to be low at worst.

Plankton

- 8.5.5.8 The sensitivity of plankton species to contaminants is assessed as low to moderate because, while contaminants can cause toxicity in planktonic species, the concentrations required to produce both lethal and sub-lethal effects are generally high. Vulnerability is therefore assessed as low at worst. Therefore, as plankton within Swansea Bay are considered to be of low importance due to their widespread nature, the overall significance of the impact on plankton is assessed as **insignificant**.

Macroalgae

- 8.5.5.9 The most frequently observed macroalgae species observed on the rocky shore within Swansea Bay, *Pelvetia canaliculata* and *Fucus spiralis*, are intolerant of heavy contamination. Both species disappeared from heavily oiled shores after the Amoco Cadiz oil spill, which demonstrated the species' high position on the shore and the long residence time of the oil on the algae before it was washed off by the tide (White, 2008; Marshall, 2005). However, macroalgae species in vicinity of the construction works are considered to have a low sensitivity to discharges and accidental spillages given that they will only be exposed while they are submerged in water and the tide will rapidly disperse any contaminants. In addition, the concentrations of contaminants required to produce both lethal and sub-lethal effects in macroalgae are generally high, with responses varying considerably between species. Vulnerability is therefore assessed as low at worst. Macroalgae within Swansea Bay are considered to be of low importance and thus the overall significance of the impact on macroalgae is assessed as **insignificant**.

Intertidal ecology

- 8.5.5.10 The sensitivity of intertidal habitats and species to contaminants is assessed as low to moderate because, although contaminants can cause toxicity in intertidal communities, the concentrations of contaminants required to produce both lethal and sub-lethal effects are generally high (although responses vary considerably between species). Furthermore, intertidal habitats and species in the vicinity of the construction works will only be exposed to any contaminants while they are submerged in water and the tide will rapidly disperse any contaminants away. Vulnerability is therefore assessed as low at worst. The importance of intertidal ecology is considered to range from low for unprotected features to high for nationally protected features. Therefore, the overall significance of discharges and accidental spillages during construction works on intertidal habitats and species is considered to be **insignificant to minor adverse**.

Subtidal ecology

- 8.5.5.11 The sensitivity of subtidal habitats and species to contaminants is assessed as low to moderate because while contaminants can cause toxicity in subtidal communities, the concentrations required to produce both lethal and sub-lethal effects are generally high (although responses vary considerably between species). Furthermore, subtidal sediments are generally at lower risk from oil spills than intertidal sediments as contaminants tend to sit on the surface of the water. Vulnerability is therefore assessed as low at worst. The importance of subtidal habitats and species is considered to range from low for unprotected features to high for nationally protected features. The overall significance of the impact on subtidal habitats and species is, therefore, assessed as **insignificant to minor adverse**.

Confidence

- 8.5.5.12 Confidence in the assessment of this pathway is considered to be medium to high as the impacts from discharges and accidental spillages on marine ecology receptors are well understood through a large number of research studies on this subject.

8.5.6 Impact Pathway 5: Introduction of non-native species during construction

General scientific context

- 8.5.6.1 Non-native, or invasive, species are described as "organisms introduced by man into places outside of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species" (IUCN, 2011). The ecological impacts of such 'biological invasions' are considered to be the second largest threat to biodiversity worldwide, after habitat loss and destruction. In the last few decades marine and freshwater systems have suffered greatly from invasive species as a result of increased global shipping (Carlton and Geller, 1993).
- 8.5.6.2 The introduction of non-native species can occur either accidentally or by intentional movement of species as a consequence of human activity (Ruiz and Carlton, 2003; Copp *et al.*, 2005 in Pearce *et al.*, 2012). Within the UK, pathways of introduction involving vessel movements (fouling of hulls and ballast water) have been identified as the highest potential risk routes for the introduction of non-native species (Carlton, 1992; Defra, 2003; Pearce *et al.*, 2012), which agrees with the fact that areas with a high volume of shipping traffic are hotspots for non-native species in British waters (Pearce *et al.*, 2012).
- 8.5.6.3 The pathways which have the potential for introducing non-native species during construction are via transport of species in ballast or bilge water, fouling of vessels' hulls and the accidental imports from materials brought into the ecosystem as a result of the Project. Construction works traffic also has the potential to transfer non-native species that are currently present within Swansea Bay to other areas.
- 8.5.6.4 The introduction of non-native species has the potential to alter interactions within existing ecological assemblages. Potential effects on native species include competition for space and resources; alteration of substrata and water conditions; predation and depletion of native species; smothering of native species; consumption of pelagic larvae and loss of prey and refuge (Sewell *et al.*, 2008).
- 8.5.6.5 There are currently considered to be 14 species of non-native marine plants and 21 species of animals recorded on Welsh coasts (Oakley Intertidal, 2009). Non-native species that feature around Swansea Bay include the slipper limpet, *Crepidula fornicata*, the seasquirt *Styela clava*, the Wireweed *Sargassum muticum* and the Australian tube worm *Ficopomatus enigmaticus*.
- 8.5.6.6 The American slipper limpet, *Crepidula fornicata*, is prevalent throughout Swansea Bay. The species was observed in a number of areas throughout Swansea Bay during the 2013 intertidal and subtidal surveys and by fishermen in the Porthcawl area, who have reported increased by-catches of slipper limpet in recent years at the expense of catching other shellfish such as oysters (see Chapter 9, Fish, Commercial and Recreational Fisheries). Slipper limpet competes for food and space with other filter-

feeding species, such as native oysters, *Ostrea edulis* and has been known to displace mussel beds¹¹ (Rayment, 2008).

- 8.5.6.7 The leathery sea squirt, *Styela clava*, has also been recorded within Swansea Bay. Sea squirts attach to solid surfaces in shallow water, especially in harbours and marinas. *Styela clava* has also been recorded on wrecks and natural rock bottoms. Colonies can occupy substantial space at high densities, overgrowing other sessile fauna and causing fouling to ships. There is some evidence that sea squirts displace native species¹².
- 8.5.6.8 Wireweed *Sargassum muticum* is currently distributed along the Welsh coastline from Swansea Bay round to East Anglesey¹³. Wireweed out-competes native species of seaweeds and seagrasses forming dense assemblages and potentially altering community structure. Wireweed is fast growing and reproduces within the first year of life by self fertilisation producing large numbers of offspring. The abundance of wireweed has been correlated with reduction in diversity of native seaweeds and other species such as sea oak. Dense stands can dominate rockpools, reducing light, increasing sedimentation and altering temperature. Wireweed is a nuisance in harbours, beaches and shallow waters and can impair recreational activities such as boating, swimming, diving, sailing and kayaking through entanglement¹⁴.
- 8.5.6.9 The Australian tube worm *F. enigmaticus* has been recorded in Swansea marina (CCSC pers. comm.). *F. enigmaticus* inhabits warm shallow sublittoral waters as well as brackish estuaries, docks and lagoons. This species forms reefs on different types of hard substrate including rocks and solid surfaces such as hulls of ships and pipes (Richards, 2008). It is a fouling species which affects ships, buoys and harbour structures¹⁵.
- 8.5.6.10 The subtidal benthic survey undertaken by Titan in May 2013 identified four species of non-natives within their samples from Swansea Bay. These include *Elminius modestus*, *Monocorophium sextonae*, *Crepidula fornicata* and *Mya arenaria*.
- 8.5.6.11 The barnacle *Elminius modestus* was identified during the 2013 subtidal benthic survey. This non-native species competes with other shallow water barnacles for space as it is able to settle at higher levels of the shore as well as deeper into subtidal levels than other barnacles (NOBANIS, 2013a). *E. modestus* grows rapidly with its initial growth rate up to 6 mm in 40 days and it produces several broods per year (JNCC, 2013b). Because it may reproduce throughout the year it has a high reproductive potential, and in some places it is the dominating barnacle species and may have completely replaced the native barnacles. *E. modestus* attaches to a wide variety of substrata including rocks, stones, shells, other crustaceans and artificial structures (Avant, 2007). It is transported as adults on ships' hulls and also as pelagic larvae in ballast water (JNCC, 2013b).
- 8.5.6.12 The amphipod *Monocorophium sextonae*, which was also recorded during the 2013 subtidal survey, lives in soft sediment, on top of other organisms such as algae and sponges and on artificial substrates, from the intertidal zone to a depth of

¹¹ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1028>

¹² <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=3430>

¹³ www.nonnativespecies.org/downloadDocument.cfm?id=249

¹⁴ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=3141>

¹⁵ <http://jncc.defra.gov.uk/page-1700>

approximately 50 meters (EOL, 2013). The origin of *M. sextonae* is unknown, however, it is considered likely that it was introduced to the UK in ballast water or on ships' hulls. The species may also be able to drift with currents, and could have spread between Britain and Ireland in this way (Naylor, 2006).

- 8.5.6.13 The soft-shelled clam *M. arenaria*, which was also found during the 2013 subtidal survey, buries itself up to 30 cm below the surface in sand, mud and clays, often in mixtures with coarse gravel. It mainly occurs in the upper intertidal zone in bays and estuaries, but also occurs in the low intertidal and shallow subtidal zones, and on occasion is reported from deeper water (Cohen, 2011). Adults are tolerant of quite large changes in salinity and temperature and can survive in an oxygen-free environment for a number of days. Hence it is common in estuaries in its native, as well as its introduced, range (NOBANIS, 2013b). *M. arenaria* spawns once or twice a year in the spring or summer and larvae are pelagic and planktotrophic for 2-3 weeks (NOBANIS, 2013b). *M. arenaria* feeds on microscopic plankton (flagellates, diatoms and bacteria) and organic detritus that it filters out of the water (Cohen, 2011).
- 8.5.6.14 Non-native species which currently have not been observed in Swansea Bay, but occur within the UK and have the potential to spread into the Bay from nearby areas include the marine bacteria *Vibrio parahaemolyticus*, the macroalgae species green sea fingers *Codium fragile* subspecies *tomentosoides* as well as the sea squirts *Didemnum vexillum* and *Botrylloides violaceus*, Zebra mussel *Dreissena polymorpha*, Manila clam *Venerupis philippinarum*, Pacific oyster *Crassostrea gigas*, Chinese mitten crab *Eriocheir sinensis* and killer shrimp *Dikerogammarus villosus*.
- 8.5.6.15 The marine bacteria strain of *Vibrio parahaemolyticus* is a fast growing and adaptable form of plankton. It is commonly found in marine and estuarine environments but is able to accumulate in shellfish causing gastroenteritis in humans. Before 2012, strains of *Vibrio parahaemolyticus* had only appeared in the Pacific Northwest (PNW) region of North America, however, in 2012 shellfish-associated outbreaks of illness in humans in Europe were linked to the *Vibrio parahaemolyticus* strains from the PNW. The introduction of these strains in Europe could be attributed to a number of factors including; ballast water exchange, the international trade and movement of shellfish produce and long-distance ocean currents (Cefas, 2013).
- 8.5.6.16 Green sea fingers *Codium fragile* subspecies *tomentosoides* is currently distributed along the South Wales coastline. It out-competes native species of seaweeds and can become the dominant canopy species, potentially altering community structure. The species is a nuisance in harbours, beaches and shallow waters and can impair recreational activities such as boating, swimming, diving, sailing and kayaking through entanglement¹⁶
- 8.5.6.17 Although a survey of Welsh marinas and harbours in 2008-2009 (Holt et al. 2009) revealed that the carpet sea squirt *Didemnum vexillum* was absent from Swansea Bay the species was recorded at Holyhead marina, Anglesey and has also been recorded in two locations in Devon (Plymouth and the Dart Estuary) (Nimmo et al. 2011). Colonies of *D. vexillum* can form extensive, thin (2-5 mm) sheets which overgrow other sessile fauna and occupy a substantial proportion of available space. Natural dispersal ability of the species is limited. Within the UK, *D. vexillum* have only been recorded in marinas

¹⁶<http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=866;>
http://www.brc.ac.uk/gbnn_admin/index.php?q=node/278

and shallow artificial structures suggesting its introduction and spread within the UK through ballast water exchange or on ships' hulls¹⁷. Similarly the colonial sea squirt, *Botrylloides violaceus*, has not yet been recorded within Swansea Bay but has been recorded at Milford Haven and Neyland (Oakley Intertidal, 2009). Sea squirts attach to solid surfaces in shallow water, especially in harbours and marinas. *Botrylloides violaceus* has also been reported on natural shores on seaweed. Colonies can occupy substantial space at high densities, overgrowing other sessile fauna and causing fouling to ships. There is some evidence that sea squirts displace native species¹⁸.

- 8.5.6.18 Zebra mussel, *D. polymorpha*, is known to be present within Cardiff Bay and has the potential to spread to Swansea Bay (Swansea Council, 2013). Zebra mussels filter large volumes of water each day which reduces the availability of nutrients and oxygen, and can cause severe habitat alterations. The species competes for space and food with native mussels and other filter-feeding organisms and can also foul boats and infrastructure¹⁹.
- 8.5.6.19 The Manila clam, *V. philippinarum*, and Pacific oyster, *C. gigas*, has also been recorded along the Welsh coastline and the south west of England²⁰ (Reid, 2009). These species form dense aggregations, excluding other species and altering habitats. The Pacific oyster is well documented along the South Wales coast, in particular Milford Haven. Recent anecdotal evidence has suggested that a few records of *C. gigas* have been recorded within Swansea Bay (CCSC pers. comm.).
- 8.5.6.20 Although currently more prevalent along the East coast of England in the River Thames and the River Medway, the Chinese mitten crab, *E. sinensis*, has also been recorded within the River Dee in North Wales and the River Tamar, Plymouth, and has the potential to spread along the coast (Reid, 2009). The species impacts native species through predation of invertebrate species and the eggs of fish, and competition for space. The Chinese mitten crab also burrows into river banks, increasing erosion and river turbidity, and causing bank collapse. The burrowing can also lead to the siltation of gravel beds used for spawning by salmon and trout²¹.
- 8.5.6.21 The killer shrimp *D. villosus* was also identified as having rapidly colonised the impounded water of the Cardiff Bay barrage and is also present within the Eglwys Nunydd Reservoir in Port Talbot. Killer shrimp require hard banks, slow flowing water and are salt tolerant so, although typically found in freshwater, they can colonise brackish coastal habitats. Killer shrimps are voracious predators of native shrimp and a wide range of other native fauna. They are likely to disrupt ecosystems through direct predation and also indirect effects across trophic levels. Loss of diversity could affect assessments of water quality whilst changes in trophic interactions could alter distributions of fish. In addition, parasites carried by killer shrimps could reduce fish stocks²².

¹⁷ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1209>

¹⁸ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=514>

¹⁹ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1250>

²⁰ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1013>

²¹ <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1379>

²² <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1219>

- 8.5.6.22 Such competition from invasive species may lead to a reduction in population numbers and biodiversity of Swansea Bay. As a result of the reduction in native species, Swansea Bay and surrounding areas could be reduced in terms of habitat quality for foraging birds and other species, due to reduced prey density.

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- 8.5.6.23 The use of vessels and infrastructure during the construction phase has the potential to generate transfer pathways for non-native species through ballast water and fouling.
- 8.5.6.24 Non-native species have the potential to be transported into and out of Swansea Bay on ships' hulls. Maintenance of hulls through regular cleaning will minimise the number of fouling organisms present. This is especially important prior to moving boats from a port in one area of the country (or world) to a port in another area. The fouling of a boat hull and other below-water surfaces can be reduced through the use of protective coatings applied to the hull. These coatings usually contain a toxic chemical (such as copper) or an irritant (such as pepper) that discourages organisms from attaching. Other coatings, such as those that are silicone-based, provide a surface that is more difficult to adhere to firmly, making cleaning of the hull less laborious. The type and concentration of coatings that can be applied to a boat hull is regulated, and can vary from country to country. Hull cleaning can take place on land or in-water. In both cases, care should be taken to prevent the organisms from being released into the water. By following best management practices, the impact of the cleaning procedure on the environment can be minimised.
- 8.5.6.25 Non-native invasive species also have the potential to be transported both into and out of Swansea Bay via ship ballast water. Sea water may be drawn into tanks when the ship is not carrying cargo, for stability, and expelled when it is no longer required. This provides a vector whereby organisms may be transported long distances.
- 8.5.6.26 Vessels are required to maintain a ballast water management plan and a ballast water record book for inspection by the harbour authority and flag state. When a vessel is required to de-ballast for safety or operational reasons this should be through an approved ballast water treatment system or a ballast water exchange should have been completed. A ballast water exchange should equate to a 95% volumetric exchange and be completed at least 50 nautical miles from land or as far as possible from the nearest land within the vessels normal trading pattern. Where possible, the exchange should be completed in waters at least 200m deep.
- 8.5.6.27 The UK is bound by international agreements such as the Convention on Biological Diversity, the United Nations Convention on the Law of the Sea, the Convention on the Conservation of Migratory Species of Wild Animals (Bonn 1979), the Convention on the Conservation of European Wildlife and Natural Habitat (Bern 1979) and the Habitats and Birds Directives. All of these aim to protect biodiversity, endangered species and habitats, and include provisions requiring measures to prevent the introduction of, or control of, non-native species, especially those that threaten native or protected species (JNCC, 2013c).
- 8.5.6.28 These commitments are expected to be subject to greater international enforcement over time. This is because compulsory treatment of ballast water may be introduced (King, 2013). In 2004 the International Maritime Organisation (IMO) adopted the

'International Convention for the Control and Management of Ships' Ballast Water and Sediments', which involved two performance standards:

- i. D1 – 95% of ships ballast to be exchanged in waters 200nm from land and at least 200m deep. Where this is not possible ballast must be exchanged no closer than 50nm to land; and
- ii. D2 – Ballast Water Treatment systems approved by the relevant administration [in each country] which treat ballast water to an efficacy of:
 - < 10 viable organisms per m³ >50 micrometres in minimum dimension.
 - <10 viable organisms per millilitre < 50 micrometres in minimum dimension and >10 micrometres in minimum dimension.

8.5.6.29 This legislation will be applicable one year after 30 countries, representing 35% of global merchant shipping tonnage, have signed up to the agreement. As at 30 September 2013, 38 countries had signed up to the agreement. However, these countries collectively are 5% short of meeting the tonnage requirement (IMO, 2013).

8.5.6.30 In addition, the European Commission published its proposals for new legislation to prevent and manage the introduction and spread of invasive non-native species on 9 September 2013. The proposal is designed to respond to increasing problems caused by invasive non-native species. It includes policy issues and also economical and ecological considerations. The proposal centres round a list of invasive alien species of EU concern, which will be drawn up with Member States using risk assessments and scientific evidence. Selected species will be banned from the EU, meaning it will not be possible to import, buy, use, release or sell them. Special measures will be taken to deal with issues arising for traders, breeders or pet owners in the transitional period. The proposal is for three types of intervention: prevention; early warning and rapid response; and management. The proposed legislation is currently being examined by the European Council and the Parliament.

8.5.6.31 In view of these existing commitments and considerations, the probability of the introduction and spread of non-native species from the Lagoon development is considered to be low. Given that the magnitude of change is unknown, magnitude ranges from negligible to large depending upon the scale and nature of any non-native species introduction. Thus the exposure ranges from negligible to low at worst.

Plankton

8.5.6.32 The sensitivity of plankton to the introduction of non-native species is considered to be low due to low risk of invasive marine bacteria being transferred from ballast water. Vulnerability is, therefore, assessed as low at worst. The importance of macroalgae is viewed as low and consequently, the overall impact is considered to be **insignificant**.

Macroalgae

8.5.6.33 The sensitivity of macroalgae to the introduction of non-native species is considered to be low to moderate due to the potential for the sea squirts *Botrylloides violaceus* and *Styela clava* and the seaweeds *Sargassum muticum* and *Codium fragile* subspecies *tomentosoides* to out-compete native species of seaweeds. Vulnerability is, therefore,

assessed as low at worst. The importance of macroalgae is viewed as low and consequently, the overall impact is considered to be **insignificant**.

Intertidal ecology

- 8.5.6.34 The sensitivity of intertidal habitats and species to non-native introductions are considered to be low to moderate due to the potential for non-native species to compete for space and food with native species. As noted above the American slipper limpet, *Crepidula fornicata*, is already prevalent throughout Swansea Bay and so would pose no additional threat to intertidal species. Therefore, vulnerability is considered to be low at worst. The importance of the habitats and species affected range from low for unprotected features to high for nationally protected features. Consequently, the overall impact is considered to be **insignificant to minor adverse significant**.

Subtidal ecology

- 8.5.6.35 The sensitivity of subtidal ecology receptors are considered to be low to moderate due to the potential introduction of Manila clam, *V. philippinarum*, and Pacific oyster, *C. gigas*. As noted above the barnacle *Elminius modestus*, amphipod *Monocorophium sextonae* and soft-shelled clam *M. arenaria* have already been identified as occurring within Swansea Bay. Therefore, these species would pose no additional threat to subtidal species. Vulnerability is considered to be low at worst. Thus, while the importance of subtidal habitats and species are considered to range from low for unprotected features to high for nationally protected features, the overall impact is considered to be **insignificant to minor adverse significant**.
- 8.5.6.36 Furthermore, the best practice guidelines relating to ballast water and hull fouling, as outlined above, will need to be adhered to to ensure that non-native species are not transferred out of the Bay during construction works.

Confidence

- 8.5.6.37 Confidence in the assessment of this impact pathway is considered to be medium as scientific understanding of the introduction of non-native species is generally good although some uncertainty still surrounds the sensitivity of certain marine ecology receptors to non-native species.

8.5.7 Impact Pathway 6: Change in habitat suitability during construction

General scientific context

- 8.5.7.1 Changes in the hydrodynamic regime during construction works, which may include localised changes in flow speeds, direction and/or waves, have the potential to cause localised disturbance of the seabed and changes to existing sedimentary processes, with concomitant effects on the community. There may also be a strong risk of temporary scouring around the ends of new physical structures and possibly wider scale changes in flow patterns that have the potential to modify local habitats and species.

Plankton

- 8.5.7.2 Potential reduction in wave action, scour and turbidity may increase the abundance and biomass of microphytobenthos as diatom abundance and biomass have been found to be higher in sheltered and less disturbed areas (Delgado *et al.*, 1991; Blanchard *et al.*,

2002). Potential reductions in bed shear stress and short-term erosion and deposition of sediment over spring/neap cycles may also increase the abundance of microphytobenthos on the remaining intertidal and shallow subtidal areas and at times result in the periodic increase of microphytobenthos abundance in the water column.

- 8.5.7.3 Studies have found that despite high turbidity severely limiting light penetration, and therefore phytoplankton growth in the Severn Estuary and Bristol Channel, some limited primary production was found to take place because of rapid vertical mixing of the water column (Joint & Pomeroy, 1981). Changes in the hydrodynamic regime may alter the degree of vertical mixing (stratification) and, therefore, influence the length of time that phytoplankton are at a suitable depth for photosynthesis to occur. This in turn may influence the distribution (abundance and biomass) of plankton species.

Macroalgae

- 8.5.7.4 High flow speeds and sediment-scour may cause macroalgae to be torn off the substratum (Francoeur and Biggs, 2006; White, 2008; Marshall, 2005), and are predicted to prevent the settlement and establishment of algal germlings. Increases in flow speeds may therefore decrease the extent of habitat suitable for macroalgae. Conversely, if current speeds decrease, areas of hard substrate may become more suitable to be colonised by macroalgae. However, the predominantly soft nature of sediments in Swansea Bay mean that attachment surfaces will be largely restricted to the new hard surfaces provided by the physical structures comprising the Offshore Works.
- 8.5.7.5 Changes in wave heights can affect the shore heights at which macroalgae can survive. For example, increased wave heights at low water, coupled with a longer high water stand may mean that the reduction in air exposure would result in species typically found lower on the shore extending their range into higher areas of the intertidal. High wave action is also known to inhibit macroalgal growth and remove macroalgae. Currents and wave action impose drag forces on all the body structures (holdfast, stipes and blades), leading to breakage and dislodgement (Mach *et al.*, 2007). These forces may be compounded by abrasion and herbivory (Mach *et al.*, 2007).
- 8.5.7.6 Reduced deposition of sediment on rock surfaces can increase the availability of hard substrate habitat for macroalgae. Conversely, increased deposition may reduce habitat suitability for many macroalgae species. Changes in the rates and patterns of erosion and deposition, resulting from implementation of the Project, may therefore alter the extent of suitable habitat for this receptor.

Intertidal ecology

- 8.5.7.7 Intertidal sandflats are highly dynamic areas that may be subject to high levels of natural stress. The nature of the substratum is, in part, determined by the hydrographic regime including water flow rate. Changes in the water flow rate will change the sediment structure and have concomitant effects on the community. Increased water flow rate may remove low water areas of sandflats or mean that some species have to reburrow more frequently which would adversely affect the energy budget of some infauna.
- 8.5.7.8 The strength of wave action also determines the topography, steepness and shore width of sandy intertidal areas (Budd, 2004). An increase in wave exposure would alter

the habitat through increased erosion (which may not be compensated for by deposition) and ultimately the nature of the substratum would change becoming coarser, forming deposits of shingle or gravel rather than sand, creating conditions outside the characterising species' habitat preference (Budd, 2004). Increased wave action may disrupt feeding and burrowing, reducing species abundance, richness and biomass (Elliott *et al.*, 1998). A decrease in water flow rate and wave action is likely to result in the accumulation of sediment. The effects of such a change will depend on the existing sediment. If the sediment is characterised by clean sand, a decrease in flow rate may result in the settlement of finer particulate and organic matter, which in turn would alter drainage and the oxygenation of the substratum. Characterising species of this habitat may not be tolerant to these changes and the accretion of muds and organic matter may encourage littoral mud communities to develop.

- 8.5.7.9 *S. alveolata* requires sufficient water action to suspend coarse sand particles in order to build tubes and so is found in quite exposed areas. However, most colonies die through eventual break up by wave action. Increased exposure will result in potentially shorter colony life. Reduced exposure may mean the population exists outside of its preferred conditions with insufficient water action to provide sand particles or food (Jackson, 2008). *S. alveolata* reefs undergo cycles of development and decay over a period of a few years. *S. alveolata* larvae spend between 6 weeks and 6 months as plankton and prefer to settle on areas already colonised by adults. Therefore, areas that are good for *S. alveolata* tend to remain so (Jackson, 2008).
- 8.5.7.10 The piddock *P. dactylus* is fixed permanently within a burrow and so is unlikely to be damaged or removed by exposure to wave action or washed away by an increase in water flow rate. However, in soft substratum habitats long term increases in wave exposure or flow rates may cause erosion and a consequent loss of habitat. Changes in wave exposure or flow rates may influence the supply of particulate matter for suspension feeding, which in turn could have an impact on growth and fecundity.
- 8.5.7.11 The existence of hydroid rockpools, dominated by ephemeral hydroids and seaweeds, is dependent on the influence of wave exposure. These species thrive due to the disturbed nature of the habitat which prevents their competitive exclusion. A reduction in wave exposure would remove this disturbance and therefore allow succession to take place in which the hydroids and ephemeral seaweeds would probably be out-competed by longer lived species. Conversely, extreme increases in wave exposure are also unlikely to be favoured by hydroid rockpools, as most of the communities associated with this habitat (e.g. *Littorina littorea*) are likely to become damaged if dislodged, and may therefore be more susceptible to predation.
- 8.5.7.12 In very exposed areas the blue mussel *M. edulis* may be susceptible to dislodgement and displacement from mussel beds where they may become buried in sand or predated on by birds. Mussels probably benefit from high current velocities supplying food (suspended particulates, benthic diatoms and phytoplankton). However, byssal thread production (and hence attachment) has been demonstrated to increase with increasing water agitation. As mussel beds increase in size and depth, individual mussels become increasingly attached to each other rather than the substratum. As a result, the bed may become destabilised and susceptible to removal by wave action or tidal scour, although mussels at the edge of the beds are often more strongly attached than mussels within the bed. With increasing wave exposure and flow rates mussel beds may become increasingly patchy and dynamic. *M. edulis* populations attached to individual boulders or cobbles on sedimentary shore (such as in Swansea Bay) are likely to be less

tolerant of increases in wave exposure and water flows, due to removal of the sediment, than individuals attached to solid rock substrate. *M. edulis* can attach and grow on a variety of substrata in a variety of water flow regimes and on wave sheltered sedimentary shores decreased wave exposure and water flow rate is likely to have little effect on mussel beds (Tyler-Walters, 2008).

- 8.5.7.13 Erosion or accretion can have an ecological effect upon the intertidal communities supported by sandflats and mudflats. Excessive sediment deposition can cause 'smothering' of benthic invertebrate fauna within sedimentary habitats. This smothering occurs where individuals are unable to migrate through any deposited sediment and their feeding and respiration apparatus becomes clogged (Elliott *et al.*, 1998). The effects of smothering on intertidal receptors are discussed in more detail in Section 8.5.4. Intertidal sandflats generally experience regular changes in accretion and deposition. Even relatively stable sandflats exist in a relatively dynamic equilibrium experiencing regular movements of sediment over their surface (especially during spring tides). This means that the invertebrate assemblages that are present are often well adapted to natural levels of siltation through life history traits and can withstand burial by repositioning in sediment or simply by extending tubes or feeding and respiration structures above the sediment surface. The effects of increased suspended sediments on intertidal receptors are discussed in Section 8.5.2.
- 8.5.7.14 Overall, the intertidal habitats and species present in Swansea Bay are considered well-adapted and resilient to the high degree of variability in the physico-chemical characteristics which cause stress. It is recognised that these characteristics of natural stress in intertidal areas (particularly in estuaries) can also be similar to those for anthropogenic stress (which has been termed the 'Estuarine Quality Paradox') (Elliott & Quintino, 2007). Therefore, in areas that are inherently variable (such as the Outer Bristol Channel), separating the various influences and detecting change caused by anthropogenic sources can be difficult (i.e. a low signal to noise ratio) (Elliott & Quintino, 2007). For example, an area which has shown a shift to sandier conditions due to changes in hydrodynamic conditions will often elicit a similar response (typically becoming characterised by a species poor macrofaunal community) regardless of the source of change (i.e. natural variation or anthropogenic impacts).

Subtidal ecology

- 8.5.7.15 Subtidal sandflats are also highly dynamic areas that may be subject to high levels of natural stress. The nature of the substratum is, in part, determined by the hydrographic regime, which in turn is important in determining species composition of the subtidal areas (Shackley and Collins, 1984).
- 8.5.7.16 Increased water flow rate and wave exposure may increase re-suspension of sediment, preventing deposition of finer particles. There would be a decrease in tube building material and the lack of deposition of particulate matter at the sediment surface, reducing food availability for deposit feeders. The resultant energy cost over one year would be likely to result in some mortality of tube builders and infauna (Rayment, 2002). Additionally, some important characterising species would become exposed to conditions outside of their habitat preference and would probably no longer be found at such a location. Polychaetes characteristic of the biotope are less likely to be affected by increased water flow rate as they burrow deeper and hunt infaunally (Budd, 2006). Wave action is a particularly important physical factor in the shallow subtidal as oscillatory wave action disturbs the sand and can cause large scale sediment transport.

Strong wave action is also likely to cause damage or withdrawal of delicate feeding and respiration structures of species resulting in loss of feeding opportunities and compromised growth (Rayment, 2002).

- 8.5.7.17 A decrease in water flow rate and wave action is likely to result in the accumulation of sediment, creating a less mobile system. The effects of such a change will depend on the existing sediment. If the sediment is characterised by clean sand, a decrease in flow rate may result in the settlement of finer particulate and organic matter to which the existing characterising species may be intolerant. Finer sediments and increased stability may enhance the survival of more sedentary forms of polychaete and bivalves and the biotope may begin to change to another (Budd, 2006).
- 8.5.7.18 Hydrodynamic currents supply food and oxygen to *Ostrea edulis* and increases in water flow may improve the availability of the suspended particles on which the oyster feeds. With increased water flow rate, the oyster filtration rate increases, up to a point where the oysters are unable to remove more particles from the passing water. However increases in water flow rate may interfere with settlement of spat. Similarly, settlement of spat may be hindered by increased wave action, and young oysters may be damaged or displaced. Growth rates of *Ostrea edulis* are faster in sheltered sites than exposed locations, however, this is thought to be attributed to the seston volume rather than flow speed or food availability (Valero, 2006; cited in Jackson and Wilding, 2009). Conversely, decreased water flow may result in increased siltation and consequential changes in substratum type. This may result in reduced weight, condition and fecundity of oysters (Jackson and Wilding, 2009).
- 8.5.7.19 On subtidal sandflats patterns of erosion or accretion can have an ecological effect upon the subtidal communities supported by them. Excessive sediment deposition can cause 'smothering' of benthic invertebrate fauna within sedimentary habitats. This smothering occurs where individuals are unable to migrate through any deposited sediment and their feeding and respiration apparatus becomes clogged (Elliott *et al.* 1998). The effects of smothering on subtidal receptors are discussed above in Section 8.5.4. Subtidal sandflats experience regular changes in accretion and deposition. Even relatively stable sandflats exist in a relatively dynamic equilibrium experiencing regular movements of sediment over their surface (especially during spring tides). This means that the invertebrate assemblages which are present are often well adapted to natural levels of siltation through life history traits and can withstand burial by repositioning in sediment or simply by extending tubes or feeding and respiration structures above the sediment surface. The effects of increased suspended sediments on subtidal receptors are discussed in Section 8.5.2.

Project impact assessment

- 8.5.7.20 The proposed capital dredging and construction works will cause a phased change to the coastal hydrodynamics and, in turn, the sediment regime within Swansea Bay, as a series of gaps in the Lagoon walls gradually shorten until closure is achieved. Most of the changes are predicted to occur within the western region of the Bay (Chapter 6, Coastal Processes). Here, the construction of the western Lagoon seawall, will result in reductions in flow velocities along the upper intertidal over the majority of the western part of the Bay, from the western tip of the Lagoon down to Mumbles. Further changes in flow direction and velocities will occur in close proximity to the structures, in which flows will largely become trained parallel to the Lagoon seawalls at certain stages of the tide, with the potential for localised flow accelerations. The presence of the western

and eastern Lagoon seawalls will also prevent westerly tidal residuals across the Bay, specifically along the intertidal, between the River Neath and the western Bay.

- 8.5.7.21 In respect of waves, the construction of the western Lagoon seawall is expected to provide additional shelter to the Swansea frontage from south-east wave conditions, whilst the initial section of the eastern Lagoon seawall will provide some limited protection to the Crymlyn Burrow frontage from waves approaching from the south-west. Additional shelter will be provided to the shoreline within the footprint of the Lagoon from both south-west and south-east wave conditions during the later phases of the construction works. Outside of the Lagoon, there is potential for increased wave heights within the Bay immediately adjacent to the south-western section of the Lagoon seawalls but also within the western region of the Bay, specifically between Mumbles Head and West Cross. Wave reflection processes along the seawall under the prevailing south-west wave conditions drive these increases in wave height. For a 10 in 1 year wave event, the coastal processes modelling predicts that wave heights will generally be increased within this area by around 0.05 to 0.25 m, with a peak slightly in excess of this at the shoreline fronting Oystermouth. Under south-east wave conditions, for a 10 in 1 year wave event, no increases in wave height (above 0.05 m) are expected to occur within Swansea Bay. Under more extreme conditions, however, the presence of the Lagoon will potentially lead to an increase in wave heights along its south-eastern side as a result of wave reflection processes. Increases in this area are expected to be in the region of 0.05 to 0.25m under an extreme 1 in 10 year wave condition. Furthermore, under this extreme condition, wave height increases have also been predicted immediately to the north of Port Talbot around the entrance to the River Afan.
- 8.5.7.22 In terms of the sediment regime in Swansea Bay, the greatest changes over the initial phase of construction are expected to occur within the western region of the Bay, with the potential for increased accumulation of fine (muddy) sediments as a result of the reduction in flow speeds. Increased rates of sedimentation will be experienced predominantly along the Swansea Channel, i.e. immediately to the west of the western Lagoon seawall, and also in the shallow subtidal areas within this region of the Bay, with accretion predicted to be in the range of 0.3 to 0.75 mm over two tides. Furthermore, the overall presence of these structures within Swansea Bay is predicted to hinder any potential transport of sand (in suspension) from east to west across the bay, i.e. from the River Neath towards Blackpill, under storm conditions (with large waves approaching from the south-west). It is during these storm conditions that wave disturbance may infrequently be sufficient to re-suspend sandy sediments within the entrance to the River Neath, which may then be subject to westerly sediment transport across the Bay under large spring tide ebb flows between *circa* high water (HW) and HW + 3 hours. Any such transport is unlikely to occur under more 'normal' tide and wave conditions. Changes to the potential aperiodic transport of sand into the western side of the Bay (from the offshore region of the outer Swansea Bay and Bristol Channel) under extreme south-east wave conditions are not expected. Overall, the potential net loss of infrequent sand supply to the western region of the Bay may slightly increase the potential for beach erosion between West Cross and Singleton Park in the long-term. The presence of the eastern Lagoon seawall is expected to greatly reduce the wave conditions currently experienced within the entrance to the River Neath (particularly to the north end of the channel), which may lead to an increased potential for sand accumulation in this area. The consequences of these changes to the Crymlyn Burrows SSSI are assessed in the Terrestrial Ecology Chapter 12.

- 8.5.7.23 In the western region of the Bay, predicted increases in wave heights resulting from wave reflection along the Lagoon seawalls (under south-west wave conditions) are likely to increase sediment disturbance across the intertidal area between Mumbles Head and West Cross. Whilst under 'normal' wave conditions this is unlikely to have any significant morphological impact, under more extreme wave events or during a prolonged stormy period over spring tides, this disturbance may lead potentially to increased erosion of the seabed sediments in this area in the long term. This will be more pronounced in close proximity to the Lagoon seawall. Whilst similar wave reflection processes are experienced in the eastern region of the bay under south-east wave conditions, these waves are typically much smaller and of a short period. As such, any increase in wave heights, and the associated impact upon morphology, is expected to be considerably less.
- 8.5.7.24 The greatest changes to the sediment regime in the final phases of the construction works are expected to occur within the area of water impounded by the Lagoon. Flow speeds are likely to be accelerated through the gap in the Lagoon seawalls on the flood tide, with the potential to remobilise and transport sand fractions into the Lagoon. Flow speeds across the Lagoon in general are envisaged to reduce. As such, suspended sediments entrained within the water column are more likely to settle to the seabed within the lagoon over HW, with flow speeds unlikely to be sufficient to remobilise a large proportion of this sediment on the subsequent ebb tide. This change will lead to increased sedimentation rates within the Lagoon, particularly that of mud. This will be further exacerbated by reduced wave disturbance of the seabed; caused by the increased shelter afforded to the Lagoon by the extensions to the eastern seawall.
- 8.5.7.25 Overall, the changes in hydrodynamics and sediment transport remain confined to Swansea Bay, and the magnitude of change is considered at worst to be medium in the context of natural variability. As these impacts are almost certain to occur, the probability of occurrence is considered as being high, with exposure to change assessed as being medium.

Plankton

- 8.5.7.26 Phytoplankton and microphytobenthos present within Swansea Bay are considered to be well adapted to natural variability in water flows and sedimentation due to the existing dynamic hydrodynamic and sediment regime conditions. The sensitivity of this receptor is therefore considered to be low, giving rise to at worst a low vulnerability. The importance of plankton is considered to be low and therefore the overall significance of changes in habitat suitability during construction is considered to be **insignificant**.

Macroalgae

- 8.5.7.27 Decreased current speeds and wave action within the Lagoon during the phased construction is likely to make the existing sea wall at the back of the site more suitable to be colonised by macroalgae. The potential colonisation of the new Lagoon seawalls during the operational phase is considered in Section 8.5.8. Conversely, increased deposition of sediment on rock surfaces as a result of reduced flows within the Lagoon may reduce the habitat suitability for many macroalgae species. Macroalgae species that occur in Swansea Bay already experience fluctuations in water flows, sedimentation and wave exposure under natural conditions. Furthermore, macroalgae will only be exposed to changes while they are submerged in water and are therefore

considered to have a low to moderate sensitivity to changes in habitat suitability as predicted by the coastal processes assessment. This receptor will therefore have a low to moderate vulnerability and given their low importance, the overall impact of changes in habitat suitability is considered to be **insignificant to minor beneficial significance**.

Intertidal ecology

- 8.5.7.28 Over the construction period, intertidal habitats in the lee of the new Lagoon structures will be subject to reduced wave disturbance and water flows, and in turn increased levels of mud/silt deposition. Any long term changes in substrate type within the Lagoon during operation which are likely to result in a change in the characterising fauna and thus biotope are assessed in more detail in Section 8.5.9. Intertidal sandflat and muddy to fine sandy sediments that dominate Swansea Bay and the other intertidal habitats and species that comprise the intertidal ecology in Swansea Bay, including *Sabellaria alveolata*, piddocks and blue mussels are considered to have at worst a low sensitivity to the predicted changes in habitat suitability during construction. This is because these habitats and species are found in varying hydrodynamic and sediment regimes and they are therefore well adapted to the scale of changes predicted which are generally within existing natural conditions. The importance of these intertidal features is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in habitat suitability is therefore considered to be **insignificant** for unprotected features and **minor adverse significance** for protected features.

Subtidal ecology

- 8.5.7.29 Subtidal muddy, sands and gravels and associated species, including the native oyster *O. edulis*, are already accustomed under normal conditions to fluctuations in hydrodynamics and sedimentation patterns and are therefore considered to have a low sensitivity to the predicted changes in habitat suitability. The importance of the subtidal ecology is considered to range from low for unprotected features to high for protected features. The overall significance of changes in habitat suitability during construction is therefore considered to be **insignificant** for unprotected features and **minor adverse significance** for protected features.

Confidence

- 8.5.7.30 There is a degree of uncertainty associated with any modelling predictions relating to changes in hydrodynamics and sediment regime. Within this assessment uncertainty has been expressed by presenting changes and exposures as ranges rather than single point values, wherever possible. Furthermore, a worst case judgement has been followed in order to ensure that the assessment is conservative and precautionary. Despite this, the impacts of these changes on marine ecology receptors are well understood through a large number of research studies on this subject. Therefore the overall confidence in the assessment of this pathway is considered to range from medium to high.

Operational Phase

8.5.8 Impact Pathway 7: Change in habitat extent during operation

General scientific context

- 8.5.8.1 Intertidal and subtidal habitats, and species which are functionally reliant on these habitats (e.g. microphytobenthos), are sensitive to direct physical loss at locations where new structures are introduced onto the seabed (i.e. within the development 'footprint' of these structures). The significance of such direct losses will vary on a site by site basis in response to differences in the extent and duration of the losses as well as the relative value of the habitats in question. As any effects are very much dependent upon site specific considerations, a generic scientific review is not appropriate and the assessment of direct changes in habitat is provided within the following project impact assessment commentary.
- 8.5.8.2 Despite the potential for some direct habitat loss, the Lagoon seawall itself has the capacity to function as an artificial reef by providing a new colonisation surface for species dependent on hard substrate (Bertelli and Powell, 2013). The very first organisms to colonise a surface in the marine environment produce a biofilm. This is comprised of diatoms, bacteria, protozoans, cyanobacteria, microalgae and macroalgal propagules (Anderson 1995 cited in Bertelli and Powell, 2013). It is widely accepted that these organisms along with the other molecules that make up the film, will influence the settlement of subsequent organisms (Yebara 2004 cited in Bertelli and Powell, 2013). The type of community that will first colonize a new structure follows a common pattern. Fast-growing algae such as *Blidingia*, *Ulva* and *Porphyra* spp. are primary colonisers. These may be replaced over time by later colonisers, typically barnacles, limpets, mussels and foliose algae (Moschella *et al.* 2005 cited in Bertelli and Powell, 2013). Local field trials around Swansea Bay for biofouling experiments identified that over nine species of algae initially colonised artificial surfaces (Bertelli and Powell, 2013). However, areas subject to high water flow may be unsuitable for macroalgae. A previous review of attached macroalgae in relation to the proposed Severn Barrage scheme suggested that hard substrates in less sheltered waters away from the banks, where flow speeds are higher, were more likely to be colonised by barnacle dominated communities, rather than macroalgae (Wilkinson, 1989). However, the nature of the colonisation will also depend on the nature of the structure, e.g. boulder mounds will be less attractive to less mobile invertebrates including limpets.
- 8.5.8.3 The presence and operation of the Project will also bring about changes in water levels which in turn will result in a change in the area of intertidal and shallow subtidal habitat both inside and outside the Lagoon. The sensitivity of each of the relevant receptors to changes in water levels is reviewed below in the following sections.

Macroalgae

- 8.5.8.4 Potential changes to water levels may increase or decrease the amount of time that macroalgal species, currently living on the existing seawall, are exposed to air. With decreased water levels, the upper limit of macroalgal distribution is likely to become depressed. Those individuals living at the highest level on the shore are living at the top of their physiological tolerance limits and so would not be likely to tolerate an increase in exposure to air. Conversely with increased water levels, macroalgae may colonise further up the shore. However, where the upper limit of the shore is restricted,

increases in water levels may 'squeeze' this habitat leading to increased competition for space between species which rely on hard substrates.

Intertidal ecology

- 8.5.8.5 A decrease in water levels is likely to increase the desiccation of the sandy sediment, especially at the top of the shore, and consequently may extend the extent of barren sands and potentially allow terrestrial plants, such as pioneer saltmarsh species to invade. Species richness may decline and favour species more tolerant of desiccation or burrowing. Providing suitable substratum was available, the extent of the biotopes may extend further down shore (Budd, 2004). An increase in water levels may move the high water mark further up shore, but this is not possible in the presence of sea defences (as in the wider Swansea Bay). If the low water mark moves inshore, the area available for intertidal species and habitats is effectively reduced, so called 'coastal squeeze'. Changes in emergence will result in a change in the structure of the intertidal community and may lead to a shift in species dominance. At most, and depending on the location, there is likely to be a change in species composition and, although the resultant community may still be characteristic of sandy shores, some species may be lost (Tyler-Walters and Marshall, 2006).
- 8.5.8.6 Decreases in water levels may cause the death of some piddock *P. dactylus* individuals at the upper limit of the species range due to an increase in emergence and risk of desiccation. Conversely increases in water levels may shift this species range up the shore (Hill, 2006).
- 8.5.8.7 Changes in water levels would change the time that hydroid rockpools were exposed to air. An increase in emergence, due to decreased water levels, would mean that shallow rock pools are at a greater risk of desiccation and extremes of temperature since the pool would be exposed to the influences of air temperature for longer. Some species, such as hydroids, may dry out at the upper reaches of the rock pool whereas other species, such as periwinkles, could move down into the wetter reaches of the pool when the rock pool was not immersed by the tide. A decrease in emergence, due to increased water levels, may mean that shallow rock pools would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rock pool may become slightly deeper. As a result, it is possible that species diversity could increase as, for example, other hydroids colonised the pool. This could result in increased competition between suspension feeders (Marshall, 2005).
- 8.5.8.8 *M. edulis* can only feed when immersed in water, therefore, decreases in water levels will affect individuals' ability to feed and their energy metabolism. Growth rates of *M. edulis* have been shown to decrease with increasing shore height and tidal exposure, due to reduced time available for feeding and reduced food availability. Therefore, there will be a position on the shore where the energetic cost of metabolism is not met by feeding. Baird (1966) estimated that the point of zero growth occurred at 55% emergence but this value will vary between shores depending on local conditions, e.g. wave splash (Baird, 1966; Holt *et al.*, 1998, both cited in Tyler-Walters, 2008). Decreased water levels will increase emergence and will also expose mussel populations to increased risk of desiccation and increased vulnerability to extreme temperatures, potentially reducing their upper limit on the shore, and reducing their extent in the intertidal. Increased water levels may allow the population to colonise further up the shore but exposes the lower limit of the population to increased predation, so that the population may effectively, move up the shore. However, *M. edulis* inhabits a wide

range of shore heights and is probably relatively tolerant of changes of emergence (Tyler-Walters, 2008).

Subtidal ecology

- 8.5.8.9 Increases in water levels increase the extent of shallow subtidal sand areas and therefore, have the potential to increase the extent of features associated with this receptor. Decreases in water levels have the opposite effect and have the potential to decrease the extent of features associated with this receptor.
- 8.5.8.10 Populations of oyster are found in the lower intertidal as well as the subtidal environments. Therefore, oysters are predicted to be tolerant of small changes in water levels. Increases in water levels may allow oyster beds to extend their range up the shore. Conversely, decreases in water level may result in less time available for feeding and individuals already at the limit of their emergence tolerance would die under further increases in emergence (Jackson and Wilding, 2009).

Project impact assessment

- 8.5.8.11 The direct and indirect changes in intertidal and subtidal habitat extent as a result of the operation of the Project assuming fixed speed and variable speed turbines have been calculated and are fully detailed within Chapter 4. They are presented in Table 8.8.

Table 8.8 Changes in intertidal and subtidal habitat extent

Location	Fixed speed turbines		Variable speed turbines	
	Intertidal (ha)	Subtidal (ha)	Intertidal (ha)	Subtidal (ha)
Loss under Lagoon wall and turbine house	-20.5	-68.5	-20.5	-68.5
Gain (lagoon wall and turbine house)	+38.7	+24.2	+38.7	+24.2
Water level change within Lagoon (fixed speed turbines)	-62.0	+62.0	0	0
Water level change outside Lagoon	-2.9	+2.9	-2.9	+2.9
Overall balance (as % of habitat within Bay)²³	-46.7 (-1.9%)	+20.6 (+0.2%)	+15.3 (+0.6%)	-41.5 (-0.4%)

- 8.5.8.12 Under the footprint of the Lagoon seawall and turbine house there will be a direct loss of 20.5ha of intertidal habitat and a direct loss of 68.5ha subtidal habitat with either fixed speed or variable speed turbines, respectively.
- 8.5.8.13 As mentioned earlier, the Lagoon seawall has the capacity to function as an artificial reef by providing a new colonisation surface for species dependent on hard substrate (Bertelli and Powell, 2013). Littoral rock biotopes designated in the Swansea Bay area give an indication of what has the potential to colonise the new hard coastal structures. The nature of the new Lagoon seawall will also determine the type of species that can colonise. The external side of the Lagoon seawall structure is proposed to be covered in rock armour of various sizes, depending on its exposure (see Project Description, Chapter 4), which may be colonised less effectively by less mobile epifauna, such as limpets.

²³ The subtidal and intertidal habitat extents within the Bay are taken as those within the Swansea Bay coastal water body as identified by the River Basin Management Plan (EA, 2009).

- 8.5.8.14 The Lagoon and turbine house therefore has the potential to create and result in a direct gain of 38.7ha of intertidal habitat and 24.2ha of subtidal habitat.
- 8.5.8.15 Changes in water levels over a tidal cycle are largely constrained to within the Lagoon itself (see Coastal Processes, Chapter 6). The operational procedure required for dual-tide power generation requires the creation of a hydrostatic head (water level difference) between the Lagoon and the rest of Swansea Bay on both the flood and ebb tide. This process results in a phasing difference between the tidal levels inside and outside the Lagoon. There are also changes caused by the operational procedure on both high and low water levels within the Lagoon. Based on water level changes identified with the use of fixed speed turbines, it is estimated that a loss of approximately 62ha of intertidal habitat and an equivalent gain of subtidal habitat will occur within the Lagoon. As discussed in Chapter 4, the potential to use variable speed turbines is also being considered. If this option were selected, pumping at the end of a tidal cycle would be used to reduce in-lagoon water level changes to negligible. Changes to water levels outside the Lagoon for both the fixed and variable speed turbines will equate to a loss of 2.9ha of intertidal habitat within the western part of the Bay and an equivalent gain in subtidal habitat.
- 8.5.8.16 Swansea Bay as a whole (taken as Mumbles to Port Talbot Harbour) comprises 2424ha of intertidal habitat and 10380ha of subtidal habitat. In the context of Swansea Bay, the overall change in habitat extent resulting from the use of the fixed speed turbines, equates to a 1.9% loss in intertidal habitat and 0.2% gain in subtidal habitat. The majority of these changes will occur within the footprint of the Lagoon with only 0.12% of intertidal habitat change and 0.03% of subtidal habitat change occurring outside the Lagoon. The use of variable speed turbines would result in a 0.6% gain in intertidal habitat and a 0.4% loss of subtidal. Although the Project will result in areas of permanent habitat change, the overall magnitude of change is considered to be at worst medium, in the context of Swansea Bay as a whole. Given the certainty of these impacts, the probability of occurrence is considered as being high, with exposure to change assessed as being medium.

Plankton

- 8.5.8.17 Given that microphytobenthos are functionally reliant on intertidal and shallow subtidal areas, the sensitivity of this receptor is considered to be moderate to changes in habitat extent, giving rise to a moderate vulnerability. The importance of plankton is low given that they are widespread and not afforded any protection and therefore the overall significance of this impact during operation is considered to be **insignificant to minor adverse** significant.

Macroalgae

- 8.5.8.18 Implementation of the Project will result in the permanent loss of intertidal and subtidal habitat under the footprint of the scheme, of which only a small proportion is rock habitat and thus suitable for macroalgae. The Lagoon structure itself, however, has the potential to provide a new colonisation surface for macroalgal species which are dependent on hard substrata, particularly on the more sheltered inside facing side of the Lagoon seawall. The marine organisms that grow in and around the Project area should give a good indication of the species that could be expected to grow on and around the Lagoon seawall. Both *Pelvetia canaliculata* and *Fucus spiralis* have been observed along the hard sea wall between the River Tawe and River Neath. This will

form the northern boundary of the Lagoon and will be linked to the new Lagoon structure creating a viable pathway through which these species can colonise the new surface. Larval supply, settlement, substratum, species interactions and physical stresses will all be critical in determining the community structure that will develop on artificial structures (Menge *et al.* 2010 cited in Bertelli and Powell, 2013).

- 8.5.8.19 The Project will result in an increase in the overall area of rocky intertidal and subtidal habitat that has the potential to be colonised by macroalgae, particularly inside the Lagoon where the flow and wave conditions will be more sheltered and thus suitable for macroalgae. The sensitivity of this receptor to changes in habitat extent is considered to be moderate although recoverability is likely to be high given that conditions are favourable for settlement in new areas of artificial hard substrate. In terms of level of protection, the importance of macroalgae is low and therefore the overall significance of changes in habitat extent as a result of the Project is considered to potentially be **insignificant to minor beneficial significant**.

Intertidal ecology

- 8.5.8.20 There will be a direct loss of intertidal habitat under the footprint of the seawalls and temporary intertidal habitat that had been created during construction of the cofferdam, permanently removing habitats and species that live on or within the habitat for the lifetime of the Project. In addition, with the use of the fixed speed turbines there will be a loss of lower shore intertidal habitat as a result of changes in water levels predominantly inside but also outside the Lagoon (see Table 8.8). Losses of lower shore intertidal habitat outside the Lagoon (2.9ha) will occur with fixed or variable speed turbines (see Table 8.8). The intertidal habitats that will be lost comprise fine sand sediment, sandy mud, mixed substrate with barnacles and periwinkles, and the BAP habitats *Sabellaria alveolata* reef and hydroid rockpools.
- 8.5.8.21 A report by SEACAMS (Appendix 8.3, Volume 3) concluded that the Lagoon structure itself has the potential to provide a new colonisation surface for species characteristic of intertidal rocky shores (Bertelli and Powell, 2013). The nature of the new Lagoon seawall will determine the type of species that can colonise. The impacts of this pathway on macroalgae are discussed above. The Swansea Bay area is dominated by soft sediments and so the Lagoon seawall will provide new hard substrate to colonise. Barnacles and limpets are already present along the Port rock wall on the upper shore in the vicinity of the Project area between the River Tawe and River Neath (see Figures 8.7 to 8.9, Volume 2). It is likely that these will colonise part of the Lagoon hard structure (particularly in areas less suitable for macroalgae, such as the external sides of the Lagoon seawall and in the vicinity of the turbine/sluice gate housing where flows will be higher).
- 8.5.8.22 Overall the sensitivity of intertidal habitats and species present in Swansea Bay to changes in habitat extent brought about by the Project is considered to be high given that the changes will be permanent and irreversible. This will result in a high vulnerability. The importance of intertidal ecology ranges from low for unprotected features to high for nationally protected features. The overall significance of changes in habitat extent during operation is considered to be **minor adverse significant** for unprotected features and **major adverse significant** for protected features/species.
- 8.5.8.23 The major adverse impacts inside the Lagoon are specifically associated with protected features, i.e. *Sabellaria* reef, hydroid rockpools and intertidal mudflat and sandflat.

Mitigation measures for the loss of these habitats are discussed further in Section 8.7. Mitigation measures include the translocation of the *Sabellaria* reef prior to construction works commencing and opportunities to encourage the settlement of *Sabellaria* larvae. Bioblocks and rock pools are also proposed to be designed into the Lagoon seawall with the aim of promoting and enhancing ecological diversity and in turn providing a biodiversity offsetting measure for these losses. The residual impact to protected features is considered to be **minor to moderate adverse significant**. As identified in Section 8.7, the proposed translocation mitigation for *Sabellaria* is not proven, but it is being implemented to optimise the potential for colonisation of the habitat created as a result of the Project, as well as for the benefit of enhancing scientific knowledge. Although factors affect the effectiveness of the outcome, and consequentially effect the confidence placed in the mitigation, it remains important to implement such measures. For the biodiversity offsetting measures, there is currently no formal guidance on the relative value of different habitats. However, the artificial rocky reef is expected to have a higher ecological value than the relatively depauperate intertidal habitat and therefore, although the change in residual impact is uncertain due to the unproven method proposed for *Sabellaria* translocation, it has been moderated to recognise the potential benefits of these measures. In addition, the extent and quality of protected intertidal habitat features will be monitored to determine the actual effects of the Project during operation and enable the results of the impact assessment to be validated (Section 8.7 and Chapter 23).

Subtidal ecology

- 8.5.8.24 There will be a direct loss of subtidal habitat under the Lagoon seawalls; permanently removing habitats and species that live on or within the habitat for the lifetime of the Project. With the use of the fixed speed turbines this loss in subtidal habitat will be offset by a gain of shallow subtidal habitat as a result of changes in water levels inside and outside the Lagoon (see Table 8.8). With the use of the variable speed turbines, the loss of subtidal habitat under the Lagoon wall will not be offset by a gain in shallow subtidal within the Lagoon, but there will be a gain in shallow subtidal habitat outside the Lagoon. The subtidal habitats likely to be lost comprise predominantly sand with some areas of sandy gravel. The Titan subtidal survey also indicated that the area of *S. alveolata* reef mapped during the intertidal surveys in 2013 also extends to the shallow subtidal of the Project area. Removal of this substratum would remove a large proportion of the tubes of this tube building species from within the Lagoon, although *S. alveolata* is also present in the wider Bay. In addition mitigation measures are proposed to minimise the effects on those present within the Lagoon footprint. A portion of the amphipod population would probably be able to escape the substratum loss through swimming but the majority of other species would be affected by these changes (Rayment, 2002).
- 8.5.8.25 As described above, the Lagoon seawall will also provide new colonisation surfaces for species which are dependent on hard substrate (Bertelli and Powell, 2013). The Swansea Bay area is dominated by soft sediments and so the Lagoon seawall will provide new hard substrate to be colonised by subtidal species.
- 8.5.8.26 Given that there are unlikely to be any oysters in the areas where habitat changes will occur in Swansea Bay, the overall vulnerability of this receptor is considered to be negligible and therefore the impact will be **insignificant**, despite their high importance in terms of level of protection. Overall, the sensitivity of the remaining subtidal habitats and species present in Swansea Bay to changes in habitat extent brought about by the

Project is considered to be high given that the changes will be permanent and irreversible. This will result in a high vulnerability. The importance of subtidal ecology ranges from low for unprotected features to high for nationally protected features, i.e. subtidal sands and gravels. The overall significance of changes in habitat extent during operation is considered to range from **minor** for unprotected features to **major adverse significant** for protected habitats taking account of the overall gain in subtidal habitat, predominantly subtidal sands and gravels, within the western part of the Bay.

- 8.5.8.27 The major adverse impacts under the Lagoon footprint are specifically associated with protected features, i.e. subtidal sands and gravels. Mitigation measures for the loss of this habitat are discussed further in Section 8.7. The design of the Lagoon wall as rocky reef habitat will also aim to promote and enhance ecological diversity and in turn provide a biodiversity offsetting measure for these losses. In addition, specific opportunities to introduce oyster into or outside the Lagoon as part of the Project are being considered for ecological and habitat quality enhancement, and may in turn be considered a biodiversity offsetting measure. The residual impact on these protected features is therefore considered to be **minor to moderate adverse significance**. For the biodiversity offsetting measures, there is currently no formal guidance on the relative value of different habitats. However, the artificial rocky reef and oyster bed are expected to have a higher ecological value than the existing subtidal sands and gravels and therefore, although the change in residual impact is uncertain, it has been moderated to recognise the potential benefits of these measures.

Confidence

- 8.5.8.28 The overall confidence in the assessment of this pathway is considered to be high as the impacts from changes in habitat extent on marine ecology receptors have been well documented through a large number of scientific studies on this subject.

8.5.9 Impact Pathway 8: Changes in habitat suitability during operation

General scientific context

- 8.5.9.1 Hydrodynamic changes (water levels, waves, flow speeds) within an estuary or coastal region, or around a new development, may lead to changes in the pattern of erosion or accretion of marine sedimentary habitats such as mudflats and sandbanks. These in turn have the potential to affect habitat quality and result in changes to the diversity, abundance and biomass of plankton, macroalgae and intertidal and subtidal habitats and species (see Section 8.5.13). The hydrodynamic changes that are predicted to occur as a result of the construction of the Lagoon are assessed in Sections 8.5.7. The hydrodynamic and sediment regime changes that are predicted to occur specifically as a result of the operation of the turbines are assessed in this Section. In addition, any changes in habitat suitability due to construction and maintenance dredging requirements within the Lagoon are assessed in this section.

Project impact assessment

- 8.5.9.2 Inside the Lagoon, the greatest changes in mean flow speeds (over spring tides) occur in close proximity to the turbines and sluice gates, where large increases in mean flow speeds are observed (see Coastal Processes Chapter 6). Outside the 'jetting' flows of these structures, particularly towards the northern shoreline edge of the Lagoon, flow speeds are greatly reduced over the flood and ebb tide in comparison to the baseline

scenario. These reductions are caused by the alteration, by the Lagoon, of natural flows within Swansea Bay over the rising flood and falling ebb tide and also through the creation of low-energy circulatory gyres either side of the jetting flows within the Lagoon.

- 8.5.9.3 At HW, both the turbines and sluice gates are closed in order to impound water within the Lagoon, thus allowing a head difference to be generated as water levels outside the Lagoon fall over the ebb tide. During this period, flow speeds across the Lagoon rapidly decrease and on reaching pre-determined head differences, the turbine gates are opened, allowing flows to pass through the turbines for ebb power generation. This process results in an acceleration of flows within the Lagoon, with greatest flows in close proximity to the turbine housing. This is followed by a continued rise in flow speeds driven by the hydrostatic head difference and the shallowing depths across the Lagoon, further exacerbated by the opening of the sluice gates at the end of the flood and ebb tide respectively (to allow maximum exchange of water between the inside and outside of the Lagoon). Over this draining period, flow directions across the Lagoon are typically aligned towards the turbine structure (i.e. south-west).
- 8.5.9.4 Both erosion and accretion of mud is predicted to occur within the Lagoon (see Coastal Processes Chapter 6). Erosion may initially occur within 400m of the turbines and sluice gates, where limited muddy sediments may be subject to mobilisation under the jetting flows passing through these structures. Beyond any initial (limited) erosion, however, these accelerated flow speeds will predominantly act in keeping sediments in suspension within this area, remobilising any sediments that may settle during slack periods. Elsewhere between the upper subtidal and lower intertidal, sedimentation is expected to be relatively high, as mud fractions will drop out of suspension during HW slack periods. Flow speeds in these areas are then insufficient to remobilise these sediments completely and the level of sedimentation within the Lagoon is anticipated to require long-term maintenance dredging.
- 8.5.9.5 The maintenance dredging that will be required inside the Lagoon during the operation of the Project (see Coastal Processes Chapter 6) will change the quality of the habitat under the footprint of any dredging through the periodic disturbance of intertidal and/or subtidal habitat. Based on the results of the modelling, increases in sedimentation (above baseline levels) are estimated to cover approximately one-third of the Lagoon during operation of the turbines. Although there will be areas within the Lagoon where maintenance dredging is avoided (e.g. safety zone around the outfall), as a worst case it has been assumed that this maintenance dredging takes place uniformly across this area. It is anticipated that maintenance dredging within the Lagoon will not need to start until 10 to 15 years after the completion of construction and then be performed approximately every two years. However, the need to do so will be monitored. Based on this monitoring a dredging strategy will be developed and a licence for disposal will be discussed and agreed with the Marine Licensing Team. Further details are included within the Adaptive Environmental Monitoring Plan (AEMP, see Appendix 23.1, Volume 3) and the Operational Environmental Management Plan (OEMP). The potential effects of changes in SSC during maintenance dredging within the Lagoon and associated disposal activities are assessed in Chapter 6 Coastal Processes.
- 8.5.9.6 The area of seabed that will be disturbed during construction dredging is predicted to coincide with the area that will be disturbed during the operation of the Lagoon, either through erosion around the turbine housing and sluice gates or as a result of sedimentation and subsequent maintenance dredging. Therefore, although the benthic

habitats within the Lagoon will begin to be disturbed during the construction phase the overall impact on habitat suitability has been assessed under this impact pathway section.

8.5.9.7 The operation of the Project will also result in changes to sand transport within Swansea Bay, although to a lesser degree (see Coastal Processes Chapter 6). For example, due to the increased flow speeds that will be experienced through the turbines and sluice gates, it is estimated that there will be sufficient energy to erode some sand and gravel sediments from the seabed up to approximately 400 m from the turbine housing both inside and outside the Lagoon. This erosion is expected to be relatively short lived due to the relatively high density of the gravelly sands and sandy gravels found at the seabed within this area of the Bay. Furthermore, increased sand transport will also be seen both in the vicinity of and through the turbines and sluice gates as sand will remain mobilised for a greater period of time under the accelerated flow conditions. As a result, a proportion of sand may additionally pass into the Lagoon over the flood tide which will contribute to sedimentation within the Lagoon and maintenance dredge requirements, although to a lesser degree than the predicted mud deposition (see above).

8.5.9.8 Overall, the operation of the Project will inherently have an impact on flow speeds and directions, and in turn the sediment regime, predominantly within the Lagoon but also in the near-field across the western region of Swansea Bay. The magnitude of these changes is considered to be medium in the context of natural variability. The probability of occurrence is considered to be high and therefore the exposure to change will be medium.

Plankton

8.5.9.9 Phytoplankton and microphytobenthos present within Swansea Bay are considered to be well adapted to natural variability in water flows and sedimentation due to the existing hydrodynamic and sediment regime conditions. Although the operation of the Project will result in changes outside the normal sedimentary conditions, this receptor is considered to have a low sensitivity to these changes given its high tolerance and rapid rates of recovery, giving rise to a low vulnerability. The importance of plankton is considered to be low and therefore the overall significance of changes in habitat suitability during operation is considered to be **insignificant**.

Macroalgae

8.5.9.10 Macroalgae species that occur in Swansea Bay already experience fluctuations in water flows and sedimentation under natural conditions. The operation of the turbines will result in a significant decrease in flows and increase in sedimentation towards the northern shoreline edge of the Lagoon. However, macroalgae will only be exposed to changes while they are submerged in water and are therefore considered to have a low sensitivity to changes in habitat suitability as predicted by the coastal processes assessment. This receptor will therefore have a low vulnerability to a change in habitat suitability during operation and given its low importance, the overall impact is considered to be **insignificant**.

Intertidal ecology

- 8.5.9.11 Intertidal sandflat and muddy to fine sandy sediments and the other intertidal habitats and species that occur within the footprint of the Lagoon, including *Sabellaria alveolata* and hydroid rockpools, are considered to have a high sensitivity to the predicted changes in flows and sedimentation within the Lagoon, together with the predicted disturbance resulting from the maintenance dredging that will be required inside the Lagoon. The importance of these intertidal features is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in habitat suitability is therefore considered to be **minor adverse significant** for unprotected features and **major adverse significant** for protected features.
- 8.5.9.12 The major adverse impacts inside the Lagoon are specifically associated with changes in habitat suitability affecting protected features, i.e. *Sabellaria* reef, hydroid rockpools and intertidal mudflat and sandflat. Mitigation measures for these impacts are presented in Section 8.7. Possible mitigation measures include the translocation of the *Sabellaria* reef prior to construction of the Project commencing, and opportunities to encourage the settlement of *Sabellaria* larvae. The Lagoon seawall will also be designed with the aim of promoting and enhancing ecological diversity through the use of bioblocks and rockpools (see Section 8.8), in turn providing biodiversity offsetting measures for the losses predicted. The residual impact to protected features is considered to be **moderate adverse significant**. As identified in Section 8.7, the proposed translocation mitigation for *Sabellaria* is not proven, but it is being implemented to optimise the potential for colonisation of the habitat created as a result of the Project, as well as for the benefit of enhancing scientific knowledge. Although factors affect the effectiveness of the outcome, and consequentially effect the confidence, placed in the mitigation it remains important to implement such measures. For the biodiversity offsetting measures, there is currently no formal guidance on the relative value of different habitats. However, the artificial rocky reef is expected to have a higher ecological value than the relatively depauperate intertidal habitat and therefore, although the change in residual impact is uncertain due to the unproven method proposed for *Sabellaria* translocation, it has been moderated to recognise the potential benefits of these measures. In addition, the extent and quality of protected intertidal habitat features will be monitored to determine the actual effects of the Project during operation and enable the results of the impact assessment to be validated (Section 8.7 and Chapter 23).

Subtidal ecology

- 8.5.9.13 Given that there are unlikely to be any oysters in the areas where habitat changes will occur in Swansea Bay, the overall vulnerability of this receptor is considered to be negligible and therefore the impact will be **insignificant**, despite their high sensitivity to deposition and high importance in terms of level of protection. Subtidal muddy, sands and gravels and associated species will not be accustomed to the predicted changes in hydrodynamics and sedimentation patterns, together with the disturbance that will take place due to construction and maintenance dredging and are therefore considered to have a high sensitivity and in turn, high vulnerability. The importance of the subtidal ecology is considered to range from low for unprotected features to high for protected features. The overall significance of changes in habitat suitability is therefore considered to be **minor adverse significant** for unprotected features and **major adverse significant** for protected features.

- 8.5.9.14 The major adverse impacts are specifically associated with protected features, i.e. subtidal sands and gravels. Mitigation measures for the loss of this habitat have been integrated into the Lagoon. In particular the design of the Lagoon seawall as rocky reef habitat aims to promote and enhance ecological diversity within the Bay and in turn provide a biodiversity offsetting measure for the losses predicted (see Section 8.8). In addition, specific opportunities to introduce oyster into or outside the Lagoon as part of the Project are being considered for ecological and habitat quality enhancement, and may in turn be considered a biodiversity offsetting measure (see Section 8.8). The residual impact on the protected features is therefore considered to be **moderate adverse significant**. For the biodiversity offsetting measures, there is currently no formal guidance on the relative value of different habitats. However, the artificial rocky reef and oyster bed are expected to have a higher ecological value than the existing subtidal sands and gravels and therefore, although the change in residual impact is uncertain, it has been moderated to recognise the potential benefits of these measures.

Confidence

- 8.5.9.15 There is a degree of uncertainty associated with any sediment modelling predictions. Within this assessment uncertainty has been expressed by presenting changes and exposures as ranges rather than single point values, wherever possible. Furthermore, a worst case judgement has been followed in order to ensure that the assessment is conservative and precautionary. However, despite this, the impacts from predicted changes on marine ecology receptors are well understood through a large number of research studies on this subject and therefore the overall confidence in the assessment of this pathway is considered to be medium to high.

8.5.10 Impact Pathway 9: Changes in water quality during operation

General scientific context

- 8.5.10.1 Changes in salinity, temperature, dissolved oxygen, nutrient concentrations and contaminants have the potential to affect the distribution and community structure of plankton, macroalgae and intertidal and subtidal ecology receptors.

Salinity

- 8.5.10.2 The distribution of zooplankton species is strongly influenced by salinity variations. The zooplankton community of the Bristol Channel, for example, is characterised by a range of estuarine and marine species. Estuarine species are by their nature tolerant of a range of salinities, whereas marine species will be more sensitive to a reduction in salinity. An increase in salinity may allow a greater incursion of marine species i.e. increasing the suitable area for these species, and a displacement of estuarine species.
- 8.5.10.3 In contrast, intertidal habitats and species, including macroalgae, are able to withstand wide variations in salinity because they are usually emerged for long periods of time, during which time receptors may be drenched in freshwater from rain. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs. Freshwater flowing seaward over sandflats has been shown to have a localised effect on species diversity and abundance (Budd, 2004). In order to tolerate salinity changes, species may osmoregulate, may stop irrigating their burrow, or may move seaward if mobile or burrow deeper into the sediment (McLusky 1989, cited in Budd, 2004). As a

consequence intertidal habitats are expected to be adapted, to a certain degree, to fluctuating salinities (Jackson, 2008; Hill, 2006; Marshall, 2005; Tyler-Walters, 2008; Budd, 2004).

- 8.5.10.4 Subtidal sandflats and mudflats occupy full salinity conditions and are therefore considered to be able to tolerate increases in salinity. The species which characterise subtidal sandflats inhabit fully saline and estuarine habitats and so may be able to tolerate significant reductions in salinity to varying degrees. For example, *Abra alba* and *Pomatoceros triqueter* are typically found in full salinity conditions and are therefore likely to be intolerant of reductions in salinity in some way. The change would be likely to cause inhibition of growth and reproduction. Exposure to low salinity may result in some mortality (Budd, 2007; Riley and Ballerstedt, 2005). However, *Spiophanes bombyx* is a euryhaline species, inhabiting fully saline and estuarine habitats and is considered likely to be tolerant of reductions in salinity (Ager, 2009). Similarly, *Ostrea edulis* colonises estuaries and coastal waters exposed to freshwater influence, although the species has a preference for more fully saline conditions. Low salinity results in a cessation of feeding, however, *Ostrea edulis* are considered tolerant of reductions in salinity. Further, while *Ostrea edulis* larva may only grow at salinities of 20 psu, they can survive at salinities as low as 15 psu (Jackson and Wilding, 2009).

Temperature

- 8.5.10.5 A study of the effects of Hinkley Point C power station on plankton (Cefas, 2011a) reviewed a series of experiments at Fawley power station which demonstrated that, in the absence of chlorination, primary production was enhanced by increased water temperature up to a discharge temperature of 23°C but, thereafter was progressively inhibited (Davis, 1983). The report concluded that the effects of thermal shock on phytoplankton were negligible. EDF (1978) contains results from laboratory experiments on the effects of thermal shock upon the diatoms *Phaeodactylum tricornutum* and *Gyrosigma spencerii*. Neither species was significantly affected when cultured at 12°C or 16°C or by thermal shocks of up to 17°C. Both species were killed at ambient temperatures of 24°C. The LT50 (lethal temperature to 50% of the species) was 36.5°C and 37°C respectively.
- 8.5.10.6 The macroalgal species *Pelvetia canaliculata* and *Fucus spiralis* are well within their temperature range in the UK. *Pelvetia canaliculata* is found in much warmer and much cooler waters than the UK as it is distributed from northern Norway to Spain. This species is likely to be able to tolerate a temperature change of 5°C in the short term and 2°C in the long-term (White, 2008). *Fucus spiralis* can tolerate temperatures from -0.5 to 28°C, with the optimum temperature for growth of the species being 15°C. The species is likely to be tolerant of a change in temperature of 2°C (Marshall, 2005). Both species showed some signs of damage during the unusually hot summer of 1983, when the average temperature was 8.3°C higher than normal. Decreases in temperature are unlikely to have any effect because the species extends into northern Norway where water temperatures are cooler (White, 2008; Marshall, 2005).
- 8.5.10.7 Many intertidal species are adapted to temperature extremes, and can alter metabolic activity, burrow deeper in sediment or move to deeper water. At low tide, air temperature becomes critically important to intertidal animals, and on sandy beaches the substratum, from the surface to a depth of several centimetres, can experience large variations in temperature during a single cycle and throughout the year (Budd, 2004). For instance, Khayrallah & Jones (1980b, cited in Budd, 2004) reported the

temperature range of sand at a depth of 1 cm during neap tides to be from -2°C in February 1973, to a maximum of 25°C in July 1977. Similarly, air temperatures can be greatly elevated on hot days and due to the shallow nature of hydroid rock pools, the water is likely to heat up quickly. Therefore, long term slight changes in temperature are unlikely to have any effect on intertidal populations. Although adapted to temperature change, severe short term change may result in seasonal reduction in species richness and abundance. For example, both *S. alveolata* and *P. dactylus* are damaged or killed by frost. In addition, growth in *S. alveolata* is inhibited below 5°C (Jackson, 2008) and *P. dactylus* consume less oxygen and siphon less actively at temperatures of 7°C (Hill, 2006). In contrast, *M. edulis* can withstand extreme cold and freezing, surviving when its tissue temperature drops to -10 °C (Williams, 1970; Seed & Suchanek, 1992, all cited in Tyler-Walters, 2008).

- 8.5.10.8 The geographic distribution of polychaete and crustacean species characteristic of subtidal sandflats extend south of the British Isles, so are likely to be tolerant of a long-term temperature increase. Infaunal species in the subtidal are likely to be protected to some extent from direct effects of acute increases in temperature by the depth of overlying water. However, increased temperatures may affect infauna indirectly, by stimulating increased bacterial activity and increased oxygen consumption (Budd, 2006). The filtration rate, metabolic rate, assimilation efficiency and growth rates of adult *Ostrea edulis* increase with temperature and growth was predicted to be optimal at 17°C or for short periods at 25°C (Korringa, 1952; Yonge, 1960; Buxton *et al.*, 1981; Hutchinson & Hawkins, 1992; Grant *et al.*, 1990; all cited in Jackson and Wilding, 2009). Again the species which characterise subtidal sandflats are likely to tolerate reductions in temperature to varying degrees. Polychaetes may be unable to build calcareous tubes below certain temperatures (e.g. 7°C for *Pomatoceros triqueter*). This means that, although adults may be able to survive a decrease in temperature, larvae would not be able to attach to the substratum (Riley and Ballerstedt, 2005). Amphipods are also reported to have low tolerance to temperature changes, retarding growth, delaying maturity, and reducing feeding rate (below approximately 10°C) (Rayment, 2002). *Ostrea edulis* growth rates are usually slower, mortality increased and spawning less frequent and reliable with low temperatures. However, oysters are able to tolerate temperatures of 10°C and can survive several weeks at 1.5°C (Hutchinson & Hawkins, 1992; Korringa, 1952; both cited in Jackson and Wilding, 2009). Low temperatures and cold summers are also correlated with poor recruitment, presumably due to reduced food availability and longer larval developmental time, especially at the northern limits of its range. Therefore, a reduction in temperature may result in reduced recruitment and a greater variation in the populations of *Ostrea edulis* (Jackson and Wilding, 2009).

Dissolved oxygen

- 8.5.10.9 The most significant factor influencing oxygenation of intertidal sandflats is considered to be the drainage of the beach which, in turn, is determined by the slope and particle size. Oxygen depletion becomes a severe problem at all states of the tide on only the finest grained beaches (Budd, 2004). Cole *et al.* (1999, cited in Jackson, 2008) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. However, most intertidal species are able to gain oxygen from the air during periods of exposure. Piddocks, for example, are able to extend their siphons into the air whilst *Littorina littorea* and *M. edulis* can endure long periods of oxygen deprivation (Hill, 2006). Piddocks have also been found living in peat with a very high concentration of hydrogen sulphide suggesting a tolerance to low oxygenation (Hill,

2006). Similarly, low oxygen levels are unlikely to affect macroalgae which are photoautotrophic and do not need any oxygen for photosynthesis.

- 8.5.10.10 Changes in a fine sand community were reported for the German Bight in an area with regular seasonal hypoxia. In 1983, oxygen levels were exceptionally low <3mg oxygen/l in large areas and <1mg oxygen/l in some areas. Species richness decreased by 30-50% and overall biomass fell. *Spiophanes bombyx* was found in small numbers at some, but not all areas, during the period of hypoxia suggesting an intermediate intolerance to changes in oxygenation (Ager, 2009). Amphipods appear not to be tolerant of reduced oxygenation and some mortality of amphipods may be expected after long exposures to low oxygen concentrations (Rayment, 2002). *Abra alba* is typically found in organically enriched sediments where it may be present in high densities. Such areas can be prone to periodic oxygen deficiency and individual growth and survival is dependent upon the maintenance of a continuous balance between high energy input (food availability) and high metabolic costs which result from periodic anaerobic metabolism and regulation of oxygen uptake. As *Abra alba* is able to shift from aerobic to anaerobic respiration, a short period of hypoxia is unlikely to have a significant effect upon the species. However, prolonged exposure to oxygen concentrations below 3mg oxygen/l may severely decrease growth and survival (Budd, 2007). There is limited information available regarding the tolerance of oysters to changes in oxygen concentration. However, reduced oxygen levels may be problematic if combined with reduced salinity where the valves are kept closed as much as possible limiting respiration (Jackson and Wilding, 2009).

Nutrients

- 8.5.10.11 Many types of phytoplankton can grow and reach high numbers when nutrients (nitrogen and phosphorus) are added by human activities. On a global basis, strong correlations have been demonstrated between total nitrogen input and phytoplankton production in estuarine and marine waters. In many temperate and polar coastal marine waters, nitrogen is the most important nutrient that limits primary production of photosynthetic organisms (Dugdale and Goering 1967; Glibert 1988). Increases in nutrient loading have been linked with the development of large biomass blooms, leading to anoxia and even toxic or harmful impacts on fisheries resources, ecosystems, and human health or recreation. Reductions in phytoplankton biomass (as chlorophyll a) or harmful algae blooms (HAB) can occur through shifts in nutrient supply ratios. Changes to nutrient enrichment can also lead to changes in species composition, with a species or group of species becoming dominant under the altered nutrient regime. In many cases, the responding dominant species are not toxic and, in fact, are beneficial to coastal productivity until they exceed the assimilative capacity of the system, after which anoxia and other adverse effects occur (Anderson *et al.*, 2002). Similarly, when nutrients are reduced, smaller phytoplankton replace diatoms, and the altered size can impact the entire food web (Smith *et al.*, 2008).
- 8.5.10.12 A reduction in the level of nutrients could reduce growth rates in the macroalgae species present in the Bay. However, *Pelvetia canaliculata*, for example, is adapted to living at low nutrient levels because it can only obtain nutrients when immersed, which may be for as little as 10% of its time (White, 2008). A slight increase in nutrients may enhance growth rates but high nutrient concentrations could lead to the overgrowth of the algae by ephemeral green algae (Marshall, 2005). However, *F. spiralis* is reported to be more common than other fucoids in the sewage polluted inner part of a fjord in Norway and so may be tolerant of high nutrient increases (Marshall, 2005).

- 8.5.10.13 Long term and/or high levels of organic enrichment may result in deoxygenation and algal blooms, which may have adverse effects on intertidal habitats and species. The effects of organic enrichment on sedimentary systems and their benthos are well documented and shows a consistent sequence of response - the Pearson-Rosenberg model (Pearson & Rosenberg, 1978, cited in Budd, 2004). Greater organic inputs, coupled with reduced oxygenation lead to conditions of slow degradation and create anaerobic chemical conditions within the sediment. In turn, microbial activity is enhanced whilst the redox potential of the sediments is reduced which in turn increases the production of hydrogen sulphide and methane. A state of anaerobiosis limits the macroinfauna to species which can form burrows or have other mechanisms to obtain their oxygen from the overlying water. Moderate enrichment provides food which enhances species abundance, whilst a mixing of organisms with different responses initially increases diversity. With greater enrichment, the diversity declines and the community becomes increasingly dominated by a few pollution tolerant, opportunistic species such as the polychaete *Capitella capitata* (Budd, 2004). In shallow rockpools an influx of nutrients could lead to an increase in the abundance of macroalgae which in turn would benefit *Littorina littorea* which grazes on it. In contrast, hydroid species may be competitively displaced by the macroalgae (Marshall, 2005). *M. edulis* may also benefit from moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material. The resultant increased food availability may increase growth rates, reproductive potential and decrease vulnerability to predators (Tyler-Walters, 2008).
- 8.5.10.14 Moderately enhanced nutrient levels may be beneficial to some subtidal characterising species, where organic matter would be used as a food resource by meiofauna and macrofauna. Secondary production would increase and a mixing of organisms with different responses increases diversity (although they would need to be tolerant of the prevailing hydrodynamic regime) (Budd, 2006). In extreme instances of enrichment, diversity would be expected to decline and the fauna become dominated by fewer opportunist species (e.g. capitellids followed by spionids). This results in an increase of abundance but a decrease in species richness eventually leading to abiotic, anoxic sediments (Ager, 2009). Oysters survive in estuarine environments which frequently have higher levels of nutrients than the open coast, therefore, nutrient concentration may have no effect on the oysters themselves. Oysters may benefit indirectly through the enhanced growth of microalgae (on which they feed) with increased levels of nutrients. However, long term or high levels of organic enrichment may result in eutrophication. *Ostrea edulis* has been reported to suffer mortality due to toxic algal blooms when large numbers of dead algal cells collect on the sea bottom, resulting in local de-oxygenation as the algae decomposes, especially in sheltered areas with little water movement (Jackson and Wilding, 2009).

Contaminants

- 8.5.10.15 The potential sensitivity of receptors and impacts of chemical contaminants (associated with runoff, stored material or accidental spillages) released accidentally into the local marine environment are discussed in detail in Section 8.5.5 above and are therefore not repeated here.

Project impact assessment

- 8.5.10.16 The Water Quality Chapter (Chapter 7) and separate Water Framework Directive (WFD) Assessment produced for the Development Consent Order (TLSB, 2014), presents the

results of the WFD assessment in relation to changes in the distribution of temperature, salinity, nutrients and dissolved oxygen in Swansea Bay following commission of the Lagoon. A summary of the results of these assessments is provided below.

- 8.5.10.17 Changes in salinity as a result of the operation of the Project are most clearly seen in the area occupied by the Lagoon where the mean salinity range is predicted to increase by between 5 to 20 psu as the low salinity waters of the Rivers Neath and Tawe are prevented from mixing with the water inside the Lagoon. Greatest increases in salinity are restricted to the shallow areas within the Lagoon. Increases in salinity are also observed in the intertidal and shallow subtidal areas along the western part of Swansea Bay where mean salinity is increased by 1 to 5 psu. This is due to the plume of the River Tawe being drawn away from the western part of Swansea Bay as it becomes 'attached' to the Lagoon seawall and also due to the flow of offshore water into the Lagoon bringing higher salinity waters into the western part of Swansea Bay. In contrast, mean salinity range is reduced by 1 to 5 psu along the eastern side of Swansea Bay as the plume from the River Neath is displaced south by the Lagoon seawall. Within the context of the naturally high variability of salinity within the Bay, particularly in the very dynamic intertidal and near shore area, the magnitude of change in salinity has been assessed as negligible. Therefore, although the probability of occurrence is high the exposure to change for all marine ecology receptors is assessed as negligible.
- 8.5.10.18 Both mean and maximum summer temperatures were assessed as being largely unaffected by the presence of the Lagoon. Average winter temperatures were marginally increased by between 0.1°C and 0.75°C in the western side of Swansea Bay, by 0.5°C to 1.0°C within the Lagoon and by up to 0.25°C along the Gower coast and towards the Afan coast. At the mouth of the River Afan a slight temperature decrease was observed with maximum differences of less than 0.25°C. The Lagoon is not predicted to impact the thermal plume from Baglan power station and no temperature hotspots were predicted. These temperature differences are within normally expected year on year variability, therefore, the magnitude of change in temperature has been assessed as negligible. Although the probability of occurrence is high the exposure to change for all marine ecology receptors is assessed as negligible.
- 8.5.10.19 With the Lagoon in place Dissolved Oxygen (DO) concentrations are largely unaffected both within and outside the Lagoon. DO concentrations are predicted to be slightly increased (0.1 mg/l) in the west of the Bay due to changes in the trajectory of the River Tawe plume and greater mixing with offshore waters. In the east of the Bay DO concentrations are reduced by around 0.1 mg/l, in response to changes in the trajectory of the River Neath plume. Within the Lagoon a drop of approximately 0.5 mg/l in DO concentration is predicted in response to reduced dispersion and re-aeration in the quieter waters of the Lagoon. Under storm conditions DO concentrations remain similar to background conditions over most of the Bay. The changes predicted are very small and would not adversely impact water quality as DO concentrations remain high. Therefore the magnitude of change is assessed as negligible. Whilst probability of occurrence is high, overall exposure to changes in DO concentrations is assessed as negligible.
- 8.5.10.20 The water quality assessment predicts that overall, as a result of the Project, nitrogen concentrations within the Lagoon and the wider Swansea Bay are reduced due to the modification of the trajectories of the plumes from the River Neath and Tawe and the generation of additional mixing with offshore waters. The net change is a general reduction of nitrogen concentrations in Swansea Bay and offshore waters, although this

is partly offset by increases in nitrogen concentrations (100 µg/l) in the transitional waters of the Rivers Tawe and Neath. Given the existing nitrogen concentrations throughout Swansea Bay, the magnitude of change is assessed as small to negligible and, although the probability of occurrence is assessed as high, exposure to change is assessed as low at worst.

- 8.5.10.21 An element of risk inherently exists that accidents or spillages could occur during the operation of the Project that would result in releases into the marine environment with potential effects on water and sediment quality and thus marine ecology receptors. There is the potential for fuel spillages and contamination arising from runoff, stored material or accidental spillage during the operational lifetime of the Project. However, given that any risk of spillages from materials stored on site is low because any potentially contaminating substances will be stored appropriately away from the marine environment (See Section 8.7), the probability of an accident or spillage event occurring is predicted to be low. Although the magnitude of any event is likely to vary from small to large depending upon the scale of the pollution event that occurs, the exposure is considered to be low at worst. Potential pollution events in the marine environment are discussed further in Chapter 7 Marine Water Quality and will be covered within the Operational Environmental Management Plan that will be produced for the Project.

Plankton

- 8.5.10.22 Plankton are not vulnerable to a negligible change in exposure as a result of potential changes in salinity, temperature or dissolved oxygen during operation of the Project. Therefore, the impact to this receptor from salinity, temperature and dissolved oxygen is considered to be **insignificant**.
- 8.5.10.23 The changes in nutrient concentrations predicted to occur as a result of the operation of the Project are not expected to significantly alter primary production or the distribution of phytoplankton within the Bay. Due to the net reduction in nitrogen concentrations in the Lagoon and its high rate of flushing, the risk of algal blooms in the Lagoon is considered to be very low. Therefore the sensitivity of plankton to changes in nutrient concentrations is assessed as low to none and overall vulnerability as low to none. As plankton within Swansea Bay are considered to be of low importance due to their widespread nature, the overall significance of nutrient changes on plankton is assessed as **insignificant**.
- 8.5.10.24 The sensitivity of plankton species to contaminants is assessed as low to moderate because, while contaminants can cause toxicity in planktonic species, the concentrations required to produce both lethal and sub-lethal effects are generally high. Vulnerability is therefore assessed as low at worst. As plankton within Swansea Bay are considered to be of low importance, the overall significance of contaminants on plankton is assessed as **insignificant**.

Macroalgae

- 8.5.10.25 Macroalgae are not vulnerable to a negligible change in exposure as a result of potential changes in salinity, temperature or dissolved oxygen during operation of the Project. Therefore, the impact to this receptor from salinity, temperature and dissolved oxygen is considered to be **insignificant**.

- 8.5.10.26 Reductions in the levels of nutrient concentrations are predicted to be reduced in the areas where macroalgae are currently distributed (predominantly along the northern wall of the Lagoon). As macroalgae species are adapted to living at low nutrient levels the sensitivity of this feature to reductions in nutrient concentrations is considered to be low. Therefore, vulnerability of macroalgae is assessed as low. As macroalgae within Swansea Bay are considered to be of low importance, the overall significance of nutrient changes on macroalgae is assessed as **insignificant**.
- 8.5.10.27 Macroalgae species in the vicinity of the Project are considered to have a low sensitivity to discharges and accidental spillages given that they will only be exposed while they are submerged in water and the tide will rapidly disperse any contaminants away. In addition, the concentrations of contaminants required to produce both lethal and sub-lethal effects in macroalgae are generally high, with responses varying considerably between species. Vulnerability is therefore assessed as low at worst. Macroalgae within Swansea Bay are considered to be of low importance thus the overall significance of contaminants on macroalgae is assessed as **insignificant**.

Intertidal ecology

- 8.5.10.28 Intertidal receptors are not vulnerable to a negligible change in exposure as a result of potential changes in salinity, temperature or dissolved oxygen during operation of the Lagoon. Therefore, the impact to this receptor from salinity, temperature and dissolved oxygen is considered to be **insignificant**.
- 8.5.10.29 Increased levels of nutrient enrichment are not predicted to lead to algal blooms or result in deoxygenation. Therefore, the intertidal habitats where this increase is predicted to occur (at the mouth of the River Neath) are predicted to have no sensitivity to increased nutrient concentrations. Intertidal habitats and species within the Lagoon and western extent of Swansea Bay are predicted to be exposed to low levels of decreased nutrients. Intertidal habitats and species in these areas are adapted to living at low nutrient levels during emergence and thus have no sensitivity to decreased nutrient concentrations. Therefore vulnerability of intertidal receptors to changes in nutrients is assessed as none. Even though the importance of intertidal ecology is considered to range from low for unprotected features to high for nationally protected features the overall significance of nutrient changes for all intertidal receptors is assessed as **insignificant**.
- 8.5.10.30 The sensitivity of intertidal habitats and species to contaminants is assessed as low to moderate because, although contaminants can cause toxicity in intertidal communities, the concentrations of contaminants required to produce both lethal and sub-lethal effects are generally high (although responses vary considerably between species). Furthermore, intertidal habitats and species in the vicinity of the Lagoon will only be exposed to any contaminants while they are submerged in water and the tide will rapidly disperse any contaminants away. Vulnerability is therefore assessed as low at worst. The importance of intertidal ecology is considered to range from low for unprotected features to high for nationally protected features. Therefore, the overall significance of contaminants on intertidal habitats and species is considered to be **insignificant** for unprotected features. In terms of nationally protected features, including *Sabellaria* reef, piddocks, hydroid rockpools and intertidal mudflats and sandflats, the impact will be **minor adverse significant**.

Subtidal ecology

- 8.5.10.31 Subtidal receptors are not vulnerable to a negligible change in exposure as a result of potential changes in salinity, temperature or dissolved oxygen during operation of the Project. Therefore, the impact to this receptor from salinity, temperature and dissolved oxygen is considered to be **insignificant**.
- 8.5.10.32 Moderately enhanced nutrient levels may be beneficial to some subtidal characterising species, where organic matter would be used as a food resource by meiofauna and macrofauna. As stated above, increased levels of nutrient enrichment are not predicted to lead to algal blooms or resultant deoxygenation. Therefore, subtidal habitats and species are predicted to have no sensitivity to the increased nutrient concentrations predicted. Similarly, subtidal receptors are considered to have no sensitivity to the decrease levels of nutrients predicted across the Bay. Therefore, vulnerability of subtidal receptors to changes in nutrients is assessed as none. Although the importance of subtidal ecology is considered to range from low for unprotected features to high for nationally protected features the overall significance of nutrient changes is assessed as **insignificant**.
- 8.5.10.33 The sensitivity of subtidal habitats and species to contaminants is assessed as low to moderate because while contaminants can cause toxicity in subtidal communities, the concentrations required to produce both lethal and sub-lethal effects are generally high (although responses vary considerably between species). Furthermore, subtidal sediments are generally at lower risk from contaminants which tend to sit on the surface of the water. Vulnerability is therefore assessed as low at worst. The importance of subtidal habitats and species are considered to range from low for unprotected features to high for nationally protected features. Therefore, the overall significance of contaminants on subtidal habitats and species is assessed as **minor adverse** for the highly protected subtidal sands and gravels and **insignificant** for the remaining subtidal habitat.

Confidence

- 8.5.10.34 Confidence in the assessment of this pathway is considered to be medium, as while there is a degree of uncertainty associated with any modelling predictions, previous data provides confidence that the range of natural variability will not be exceeded.

8.5.11 Impact Pathway 10: Changes in suspended sediment concentrations during operation

General scientific context

- 8.5.11.1 The maintenance dredging and disposal that is required inside the Lagoon during the operation of the Project (see Coastal Processes, Chapter 6) will lead to changes in SSC and subsequent changes in turbidity which in turn may affect the distribution and health of plankton, macroalgae, intertidal and subtidal habitats and species. The presence of the Lagoon and operation of the turbines may also lead to changes in the sediment regime and patterns of accretion and erosion within and outside of the Lagoon which have already been assessed (see Sections 8.5.7 and 8.5.9).
- 8.5.11.2 Potential reductions in turbidity as a result of decreases in SSC may be expected to enhance the abundance and biomass of phytoplankton in the water column through increased light penetration, and may extend habitat suitable for macroalgal

colonisation. Conversely increases in SSC and turbidity may limit light penetration and decrease the depth of the photic zone in this region, in turn reducing the abundance of plankton in the Bay and restricting the extent of suitable habitat for macroalgae species.

- 8.5.11.3 The impacts of changes to suspended sediment concentrations on receptors were discussed in more detail in Section 8.5.2 for the construction phase. The same effects will be true for the operational phase and as such the information is not repeated here.

Project impact assessment

- 8.5.11.4 It is estimated that accretion within the Lagoon will likely represent an annual volume of between 570,000 to 920,000 m³ (Coastal Processes, Chapter 6). It is expected that a large quantity of this sediment would need to be maintenance dredged, in order for the Project to maintain effective power generation. It is anticipated that maintenance dredging within the Lagoon will not need to start until 10 to 15 years after the completion of construction and then performed every two years. However, the need to do so will be monitored and, based on this monitoring, a dredging strategy will be developed and a licence for disposal will be discussed and agreed with the Marine Licensing Team. Further details are included within the AEMP and the OEMP. The coastal processes modelling predicts that within the Lagoon, sediments mobilised during the maintenance dredging will be widely dispersed. Outside the Lagoon, sediments will be mobilised in close vicinity (within approximately 400m) to the turbine housing (see Coastal Processes, Chapter 6). However, these changes are relatively short lived with increases in SSC largely dissipating to background concentrations within a spring-neap tidal cycle on cessation of maintenance dredging.
- 8.5.11.5 Any sediment dredged from within the Lagoon will be disposed at the Swansea (Outer) licensed deposit ground (LU130). The deposit ground is highly dispersive for maintenance dredge sediment and for the period 1986 to 2010 received on average approximately 2.6 million wet tonnes per annum of fine sediments (both mud and sand). The new requirement for the Lagoon dredge volume would, therefore, represent an increase of between 34% and 55% of the average sediment volume received at the deposit ground. It should be noted, however, that the deposit ground has received significantly greater volumes of sediment in the past, with approximately 9.1 million wet tonnes disposed in 1996 alone, the majority of which was quickly dispersed with little change occurring to the seabed of the deposit ground.
- 8.5.11.6 In terms of the dispersion of dredged sediments deposited at the Swansea (Outer) licensed disposal ground (LU130), the total spatial extent of sediment is predicted to be circa 12 km to the west and up to approximately 20 km to the east (just beyond Porthcawl), with this variation being driven by the characteristic asymmetry in the tide within the Bristol Channel (Chapter 6 Coastal Processes). Due to these tidal characteristics of the Central Bristol Channel, there is a very limited exchange of suspended sediments from the deposit ground to Swansea Bay, with increases in SSC constrained to the deeper central region of the Bay. Following the cessation of the disposal activities, increases in SSC (above background) anywhere along the extent of the sediment plume will be indistinguishable from natural background variations within 1 to 2 weeks.
- 8.5.11.7 The overall magnitude of change during maintenance dredging and disposal is considered to be medium due to the extent of coverage of the plume. The probability of occurrence is high on the assumption that maintenance dredging and disposal will be

undertaken during the operational phase of the Project. On this basis, the exposure to change is therefore considered to be medium.

Plankton

- 8.5.11.8 Background levels of suspended sediment are naturally high in the Bristol Channel and within Swansea Bay (Chapter 6 Coastal Processes) and plankton are already tolerant to existing changes in the sediment regime (e.g. during natural storm events, maintenance dredging activities in navigation channels and deposit of sediments at the licensed disposal ground). The sensitivity of this receptor is therefore considered to be low, giving rise to at worst a low vulnerability. The importance of plankton is considered to be low given that they are widespread and not afforded any protection and therefore the overall significance of changes in SSC is considered to be **insignificant**.

Macroalgae

- 8.5.11.9 Swansea Bay has naturally high levels of suspended sediments and therefore it can be assumed that the macroalgae present would be tolerant of such conditions. The sensitivity of this receptor is considered to be at worst low (see Section 8.5.2), giving rise to a low vulnerability. The importance of macroalgae is considered to be low in terms of their level of protection and therefore the overall significance of changes in SSC during maintenance dredging is considered to be **insignificant**.
- 8.5.11.10 This receptor will not be impacted by changes in SSC brought about during the disposal of maintenance dredged material at the Swansea (Outer) licensed disposal ground (LU130).

Intertidal ecology

- 8.5.11.11 The overall sensitivity of the intertidal ecology receptor is considered to be at worst low, giving rise to a low vulnerability. The importance of intertidal ecology is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in SSC during maintenance dredging and disposal activities is therefore considered to be **insignificant** for unprotected features and **minor adverse significant** for protected features.

Subtidal ecology

- 8.5.11.12 Given that there are unlikely to be any oysters in the areas where changes are predicted to occur, the overall vulnerability of this receptor is considered to be negligible and therefore the impact will be **insignificant**, despite their high sensitivity to deposition and high importance in terms of level of protection. The overall sensitivity of the other subtidal habitats and species which occur in the study area is considered to be at worst low, giving rise to a low vulnerability during maintenance dredging and disposal activities. The importance of subtidal ecology is considered to range from low for unprotected features to high for protected features, i.e. subtidal sands and gravels. The overall significance of changes in SSC during disposal activities is assessed as **insignificant** for unprotected features and **minor adverse significant** for protected features.

Confidence

- 8.5.11.13 There is a degree of uncertainty associated with any hydrodynamic and sediment modelling predictions. Within this assessment uncertainty has been expressed by presenting changes and exposures as ranges rather than single point values, wherever possible. Furthermore, a worst case judgement has been followed in order to ensure that the assessment is conservative and precautionary. Despite this, the sensitivity of marine ecology features to changes in SSC is well understood through a large body of scientific evidence. Therefore the overall confidence in the assessment of this pathway is considered to be medium to high.

8.5.12 Impact Pathway 11: Damage/obstruction to planktonic species during operation

General scientific context

- 8.5.12.1 There is a risk that possible damage to zooplankton may occur on passing through operating turbines or that holoplankton may be stripped of eggs during passage through the turbines with implications for recruitment success and in turn the population. Chapter 9 (Fish) identifies that no studies on effects of tidal turbines on eggs and juvenile stages of fish have been identified. However, studies carried out in freshwater environments in the context of hydropower have indicated that bulb turbines have a relatively low impact on early life stages of fish. Shear forces and pressure changes created by turbines are thought to have potential effects on around 5% of ichthyoplankton, whilst blade strike is thought to affect around 0.1 % of fish eggs < 1 mm and < 2 % of fish larvae (Cada, 1990). Pressure changes in tidal power turbines are small compared with most inland hydropower schemes and therefore pressure-related effects are likely to be less than 5%. Chapter 9 (Fish) identifies that estimated STRIKER v.4 model figures for pressure effects on adult fish range are 0.33% to 2.6 %, offer the best indication of likely effects of turbine passage on ichthyoplankton, as the mechanisms for injury are likely to be similar.
- 8.5.12.2 In addition, many mobile epibenthic species undertake seasonal migrations and any physical obstructions may interfere with these and act as barriers to recruitment and connectivity through damage to individuals.
- 8.5.12.3 Changes to the tidal excursion may also reduce the transport of larvae and plankton. A decrease in the flushing regime and retention of plankton has the potential to influence their distribution. This is likely to be of greatest concern to mobile epibenthic species and the meroplankton component of the zooplankton community (i.e. pelagic larval phases of macrozooplankton, such as crabs and mussels), where migration is an important component of their life cycle.

Project impact assessment

- 8.5.12.4 Although the Lagoon seawalls are a barrier to seasonal migrations of plankton and epibenthic species, the area occupied by the Lagoon is relatively small compared to the total area of the Swansea Bay and Bristol Channel and therefore only a relatively small proportion of the plankton and epibenthic population will be exposed to a risk of physiological damage. The overall magnitude of change is therefore considered to be small to medium. The risk associated with this pathway is uncertain as there is limited scientific literature available about this subject and therefore the probability of

occurrence is considered to be medium, resulting in a negligible to medium exposure to change.

Plankton

- 8.5.12.5 Taking account of the small body size of zooplankton, the risk of damage as they pass through the turbines is likely to be negligible. Egg bearing holoplankton are likely to be more sensitive, although the sensitivity at worst is considered to be low given their small size. The vulnerability of this receptor to damage/obstruction during operation will range from none to low. Taking account of the low importance of plankton in terms of protection, the overall significance of this impact is considered to be **insignificant**. The aim of the Project is to maximise the exchange of tidal water through the turbines, and therefore given that there is unlikely to be any damage to zooplankton, including the larval phase of macrobenthic communities (meroplankton), and that zooplankton generally move passively with currents, the Project is not considered to result in a barrier to the movement of zooplankton and thus larval supply.

Macroalgae

- 8.5.12.6 This pathway is not considered relevant to macroalgae and has therefore not been assessed for this receptor.

Intertidal ecology

- 8.5.12.7 This pathway is not considered relevant to intertidal ecology and has therefore not been assessed for this receptor.

Subtidal ecology

- 8.5.12.8 Epibenthic species can be larger than zooplankton and therefore have a slightly greater risk of being damaged as they pass through the turbines. Overall, based on available scientific evidence, the sensitivity is considered to be low at worst for egg-bearing individuals. The vulnerability of this receptor to this pathway will therefore be low. Given the low importance of epibenthic species in terms of protection, the overall significance of this impact is considered to be **insignificant**.

Confidence

- 8.5.12.9 Confidence in the assessment of this pathway is considered to be low, given the lack of directly relevant empirical data and scientific evidence on this topic.

8.5.13 Impact Pathway 12: Changes in the structure and function of biological assemblages as a result of changes in biological interactions during operation

General scientific context

- 8.5.13.1 Changes in phytoplankton biomass/abundance resulting from implementation of the Project may have the potential to affect other receptors through trophic linkages. Enhanced phytoplankton growth may increase food availability to zooplankton and suspension feeders such as bivalves and polychaete worms. Increases in microphytobenthos may support sediment grazers such as mud snails, *Hydrobia ulva*. The input of extra organic matter into the ecosystem may also support populations of meiofauna and macroinvertebrates that feed on decaying organic matter in sediments.

These changes in production are likely to affect higher trophic levels and benefit fish and birds. Conversely decreases in plankton and microphytobenthos may decrease primary production and food availability for suspension feeders and sediment grazers, impacting on higher trophic levels, including fish and birds.

- 8.5.13.2 The Project will provide a substantial new area of artificial hard substrate which in turn may, if conditions are suitable, result in increased biological diversity, abundance and biomass of macroalgal species. This may lead to changes in the relative dominance of particular taxa. For example, grazing by invertebrates such as limpets has a big impact on the survival of algal germlings and seedlings (Hawkins & Hartnoll, 1983). This may lead to changes in the composition of the biological assemblage on rocky shores and other hard substrates and have the potential to modify the distribution patterns of macroalgal species. However, it is difficult to disentangle factors such as interspecific competition and predation from other physical and biological factors that will shape the structure of the biological assemblage.
- 8.5.13.3 The prevailing sedimentary and hydrodynamic regimes and water quality are important factors structuring the biological assemblage. Changes in physical and chemical parameters may potentially introduce greater competition for space and food resources and change predator-prey relationships. In terms of the intertidal and subtidal ecology receptors, this may lead to changes in the benthic assemblage including the relative dominance of particular taxa. Any changes in the biomass and abundance of intertidal species have the potential to modify trophic linkages to higher consumers such as birds and fish.
- 8.5.13.4 Changes in water levels may affect some species, although many found in the intertidal sands also extend into the subtidal zone, and vice versa, so that changes in water levels and the tidal curve resulting in changes in inundation and emersion patterns may have fewer physiological effects on these species. The sensitivity of receptors to changes in water levels has already been assessed in Section 8.5.9.
- 8.5.13.5 The sediment infauna associated with intertidal and subtidal sandflats and mudflats live in the upper layers of sediment. If these surficial sediments were removed due to changes in erosion rates this would remove species, although recolonisation would be expected to occur following the deposition of suitable material. If deposition rates increase leading to accretion then animals could become smothered if the deposition rate exceeds their tolerance to burial.
- 8.5.13.6 Currently bed shear stresses and sediment instability influence the biological assemblages that occur in sand sediments. Fauna in areas of coarse sands, which are subject to high-energy conditions, are mobile rather than attached, or are protected by thick shells. Increased stability resulting from less dynamic, variable conditions may increase the proportion of silt in sediments. The composition of the biological assemblage is strongly linked to sediment type due to a number of parameters e.g. stability, cohesiveness, water content, oxygen content, organic matter content. Benthic infaunal species, for example, are sensitive to changes in sediment as many are adapted to burrow through certain grades of material (Trueman & Ansell, 1969). Changes in sediment stability are also likely to alter the proportions of suspension and deposit feeders, as different feeding types are facilitated or inhibited and hence lead to changes in the trophic structure of the assemblage (Rhoads and Young, 1970). Increased deposition of fine sediments may also lead to increased habitat suitability for certain benthic invertebrates, resulting in an increased diversity and abundance. In turn this

would increase the food resource available to other species such as fish. Reduced sediment mobility may also encourage colonisation of coarse sands but it should be noted that these areas, even when relatively stable do not support highly diverse communities.

8.5.13.7 Sandbanks are usually dependent on the input of colonising larvae to maintain the assemblage as few species present have benthic reproduction. This means that disruption to the water currents may alter larval supply and again lead to changes in the biological assemblage present (Elliott *et al.*, 1998). Increased light penetration due to a decrease in suspended sediment concentrations may increase primary productivity in sandbanks by microalgae and macroalgae (if tides, waves and currents and associated sediments allow). Altered production may change the trophic structure and function of the biological assemblage.

8.5.13.8 Mobile epibenthos on shores tend to occur in defined zones but these patterns are not as clear as those of sedentary organisms. Changes in water level and tidal regime, leading to unusual tidal curves would therefore be predicted to change the characteristics of these zones. However, epibenthic species including crabs, mysids, crangonid and caridean shrimps are mobile and capable of migrating to more suitable habitats in response to changes.

Project impact assessment

8.5.13.9 Overall, the operation of the Project could potentially change the structure and function of biological assemblages as a result of changes in biological interactions. The magnitude of this change and probability of occurrence, however, are considered to be negligible given that water quality will not change significantly (see Section 8.5.10) and flushing of the Lagoon will be regular. The overall exposure to change will therefore be negligible.

Plankton

8.5.13.10 The sensitivity of plankton to these changes is considered to be low given their high tolerance and rapid rates of recovery. This receptor, however, will not be vulnerable to a negligible change in exposure. The importance of plankton is considered to be low and therefore the overall significance of changes in the structure and function of this receptor during operation is considered to be **insignificant**.

Macroalgae

8.5.13.11 The sensitivity of macroalgae to these changes is considered to be low given that they will only be exposed to changes whilst submerged in water at high states of the tide. This receptor, however, will not be vulnerable to a negligible change in exposure. The importance of macroalgae is considered to be low and therefore the overall significance of changes in the structure and function of this receptor during operation is considered to be **insignificant**.

Intertidal ecology

8.5.13.12 The sensitivity of intertidal habitats and species to these changes is considered to be high based on the scientific review above, however given that the level of exposure will be negligible, the receptor will not be vulnerable. The importance of these intertidal

features is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in the structure and function of this receptor during operation is considered to be **insignificant**.

Subtidal ecology

- 8.5.13.13 The sensitivity of subtidal habitats and species to these changes is considered to be high based on the scientific review above, however given that the level of exposure will be negligible, the receptor will not be vulnerable. The importance of these subtidal features is considered to range from low for unprotected features to high for nationally protected features. The overall significance of changes in the structure and function of this receptor during operation is considered to be **insignificant**.

Confidence

- 8.5.13.14 Confidence in the assessment of this pathway is considered to be low, given the complexity of biological community relationships and the lack of a clear causal link between changes in the structure and function of biological assemblages and changes brought about as a result of the Project.

8.5.14 Impact Pathway 13: Introduction of non-native species during operation

General scientific context

- 8.5.14.1 As described in Section 8.5.6, non-native, or invasive, species are "organisms introduced by man into places outside of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species" (IUCN, 2011). The introduction of non-native species has the potential to alter interactions within existing assemblages. Potential effects on native species include; competition for space and resources; alteration of substrata and water conditions; predation and depletion of native species; smothering of native species; consumption of pelagic larvae and loss of prey and refuge (Sewell *et al.*, 2008). The introduction of non-native species can occur either accidentally or by intentional movement of species as a consequence of human activity (Ruiz and Carlton, 2003; Copp *et al.*, 2005; cited in Pearce *et al.*, 2012).
- 8.5.14.2 The introduction of invasive non-native species as a result of the use of construction vessels and shipping is described in Section 8.5.6. However, the presence of artificial structures also provides a pathway through which non-native species can establish themselves. Artificial structures provide material for attachment, similar to natural hard substratum, which would create a new colonising surface for non-native species, acting as a corridor for their growth and expansion (Bulleri and Airoldi, 2005; Bertelli and Powell, 2013). Some studies have found artificial substrates have had higher abundances of non-native species in comparison to adjacent natural substrates. In addition, changes in the suitability of existing habitats may make habitats more suitable for invasive non-native species.
- 8.5.14.3 The non-native species which currently occur in Swansea Bay, as well as those which are currently not present but have the potential to spread to Swansea Bay have been discussed in detail in Section 8.5.6.

Project impact assessment

- 8.5.14.4 By following the guidance and legislation as detailed in Section 8.5.6, the introduction of non-native species through ballast water exchange and on ships' hulls will be minimised and therefore the probability of occurrence is low. However, during the operational phase the physical presence of the Lagoon seawall will also create colonising space for non-native species. Changes in existing habitat suitability may also impact the introduction and spread of non-native species, for example the carpet sea squirt *Didemnum vexillum* may thrive in the relatively sheltered environment on the inside of the Lagoon seawall and in the shallow subtidal areas. In addition maintenance dredging may remove some species of non-natives present in Swansea Bay e.g. the slipper limpet *C. fornicata* and translocate them to the disposal site. It is considered likely that the majority of *C. fornicata*, and other non-native species, would perish in this situation and would not survive at the disposal site.
- 8.5.14.5 The introduction of the Lagoon seawall hard substrate and any associated changes in habitat suitability as a result of the operation of the Project are considered to be the pathways with the greatest opportunity for the colonisation of non-native species into Swansea Bay, providing a 'stepping stone' for expansion and distribution of species. Warm-water species, for example, reached natural shores of the Isle of White by using artificial coastal defence structures as intermediate steps (Keith et al. 2011, Mieszkowska et al. 2006). Some studies have found artificial substrates have had higher abundances of non-native species in comparison to adjacent natural substrates. Examples include the green alga *Codium fragile* in the Adriatic and the colonial tunicates *Botryllodes violaceus* and *Botryllus scholasseri* in Maine, USA (Bertelli and Powell, 2013). Individual species may be favoured with knock-on effects on communities which could differ from natural assemblages, and they may even influence the biodiversity of surrounding areas (Inger et al. 2009). The probability of occurrence for these pathways is considered to be low to medium. The magnitude of change as a result of any non-native introduction is considered to range from negligible to large depending upon the scale and nature of any introduction. Therefore the exposure to change is considered to range from negligible to medium.

Plankton

- 8.5.14.6 This impact pathway is not considered relevant to plankton and has therefore not been assessed.

Macroalgae

- 8.5.14.7 *Sargassum muticum* and *Codium fragile* species grow on hard substrate in shallow waters, therefore, the sheltered surfaces within the Lagoon may provide suitable colonisation substrate. However, the high flow speeds around the turbine housing are likely to prevent colonisation of surfaces near to the turbine housing by these species, in particular *C. fragile* subspecies *tomentosoides* which requires shelter from waves and strong currents. The sensitivity of macroalgae to the introduction of non-native species is considered to be low to moderate with the vulnerability assessed as moderate at worst. The importance of the habitats affected are viewed as low and consequently, the overall impact is considered to be **insignificant to minor adverse significant**.

Intertidal ecology

- 8.5.14.8 The sensitivity of intertidal habitats and species to non-native introductions are considered to vary from low to moderate due to the potential for non-native species to compete for space and food with nativespecies. As noted above the American slipper limpet, *Crepidula fornicata*, is already prevalent throughout Swansea Bay and so would pose no additional threat to intertidal species. Therefore, vulnerability is also considered to range from none (where already present) to moderate (where the Project might allow colonisation). The importance of the habitats and species affected range from low for unprotected features to high for nationally protected features. Consequently, the overall impact for the introduction and spread of non-native species is considered to range from **insignificant to minor adverse significant** for unprotected features and **insignificant to moderate adverse significant** for protected features.
- 8.5.14.9 The residual impact of the potential introduction of non-native species on intertidal and subtidal ecology during operation of the Project can be limited by following best practice guidelines (in addition to following the guidelines on ballast water exchange and hull fouling described in Section 8.5.6) which are detailed in Section 8.7. The application of these best practice mitigation measures will reduce the residual impact to intertidal features to **insignificant to minor adverse significant** for protected features. In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon seawall during operation of the Project.

Subtidal ecology

- 8.5.14.10 The sensitivity of subtidal ecology receptors to non-native introductions are considered to range from low to moderate due to the potential introduction of Manila clam, *V. philippinarum*, and Pacific oyster, *C. gigas*. As noted above the barnacle *Elminius modestus*, amphipod *Monocorophium sextonae* and soft-shelled clam *M. arenaria* have already been identified as occurring within Swansea Bay. Therefore, these species would pose no additional threat to subtidal species. Consequently, vulnerability is considered to range form none (where already present) to moderate (where the Project might allow colonisation). The importance of subtidal habitats and species are considered to range from low for unprotected features to high for nationally protected features. Therefore, the overall impact of the introduction and spread of non-native species is considered to range from **insignificant to minor adverse significant** for unprotected features and **insignificant to moderate adverse significant** for protected features.
- 8.5.14.11 The application of the best practice mitigation measures (as detailed in Section 8.7) will reduce the residual impact to subtidal features to **insignificant to minor adverse significant**. In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon seawall during operation (See Appendix 23.1, Volume 3).

Confidence

- 8.5.14.12 Confidence in the assessment of this impact pathway is considered to be medium as scientific understanding of the introduction of non-native species is generally good although some uncertainty still surrounds the sensitivity of certain marine ecology receptors to non-native species.

8.5.15 Decommissioning Phase

8.5.15.1 In terms of decommissioning, two options currently being considered. The options vary in terms of physical intervention. The decommissioning options are:

- I. at the end of the working life of the facility, the turbines and sluice gates could be removed, and the tide allowed to flow through the resultant gaps in the structure; and
- II. it is equally likely that at the nominal end of the working life of this facility, the technology relating to power generation by tidal lagoons will have further developed, and the Project will have been progressively updated so that the Project could be kept in use as a generating station, and would not require decommissioning.

8.5.15.2 The effects of decommissioning would therefore be different for each of the options. If the Project's operation life is extended through ongoing updates, then the impacts would be the same as those identified for the operational phase, subject to any improvements due to increased understanding and technological advances. It is anticipated that the works to maintain, replace or remove the turbines and sluice gates would be undertaken from the turbine/sluice gate structure using the overhead gantry cranes. As such the potential impacts are considered to be negligible to marine ecology receptors compared to those identified for the construction phase.

8.5.15.3 The removal of the turbines and sluice gates would result in the water exchange within Swansea Bay being largely reinstated. There will still be a change to the flow and sedimentary regimes but to a lesser degree than during the operational phase, and in turn this is considered to result in a reduced overall impact to marine ecology receptors compared to the operational phase. It is probable that sedimentation will settle inside the Lagoon if it is not removed by dredging. In the long-term, this would result in seabed levels increasing and extensive intertidal mudflat and saltmarsh are likely to occur. In time, it is likely that decommissioning would result in a change in habitat within the Lagoon to that of mudflat/saltmarsh.

8.5.15.4 Thus actual decommissioning as currently proposed is likely to result in change to the physical environment that will develop during the operation of the Lagoon for energy generation. Whilst this is likely to be a significant change to the environment, in 120 years' time such changes (to the future baseline environment) may be seen as beneficial and not adverse.

8.6 Cumulative and in-combination effects

8.6.0.1 The development of the Project will take place alongside other plans, projects and activities. These have the potential to result in additional or modified impacts on the same receptors as those identified from the Project resulting in a cumulative and/or in-combination impact.

8.6.0.2 Based on consultation, a number of plans and projects have been identified which are potentially relevant in terms of cumulative and in-combination effects as outlined in Chapter 2: EIA Process and Assessment of Significance. These are listed in Table 8.9 below and an initial screening has been undertaken to identify those which have connectivity with the Project and have been considered further in the cumulative and in-combination assessment.

Table 8.9 Summary of plans and projects in the Wider Study Area

Projects	Stage in Planning Process	Preliminary Screening
Swansea University Bay Campus, adjacent to Crymlyn Burrows.	Construction Feb 2013 – Sept 2015.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
St Modwens land development- east of Swansea Docks, to west of Neath estuary.	Remediation of land, and potential future developments – no details available.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Mumbles pier, foreshore and coastal strip redevelopment	Due to be completed by the end of 2013.	Construction will be completed prior to the Lagoon construction. Mitigation measures will be put in place during construction to reduce the impacts on both the subtidal and intertidal habitats. In addition the majority of the affected habitat will be common to the wider area and it is anticipated that a rapid recovery will follow the completion of the works. No impacts will occur during operation beyond that currently experienced from the pier. Overall, therefore, there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology.
Construction of new RNLI Lifeboat Station, Mumbles	Expected completion 2014.	Construction of the new RNLI Lifeboat Station will be completed prior to the Project construction. The changes to coastal processes during operation are negligible and not anticipated to affect benthic communities (Royal Haskoning, 2010). However, the development will provide an area of new hard substrate which could result in potential cumulative/in-combination impacts in relation to the potential colonisation by non-native species. This has been assessed further in below.
SA1 development, Swansea	Development currently taking place. Completion date unknown.	Onshore works and therefore no cumulative/in-combination impacts anticipated.
Construction of the southern access road to Coed Darcy Urban Village, crossing nearby Crymlyn Bog.	Yet to commence.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Swansea Boulevard project- work between Princess Way and The Strand, and the River Tawe bridges and The Strand.	Phase to be complete in November 2013. Phase 2 to start 2014.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Wind turbine- on Welsh water site on Fabian Way.	Application – Unsuccessful 25/10/2013.	Not considered
Five wind turbines- at Mynydd Marchywel between Rhos and Cilfrew Neath	Submitted Jan 2012. Consultation finished Jan 2013. Still in planning.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Sixteen wind turbines- at Mynydd Y Gwair, Swansea	Approved – unknown construction timetable.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Five wind turbines- on land at Mynydd Brombil Farm, Margam Port Talbot	Submitted June 2012, still in planning. Consultation finishes April 2013	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Atlantic Array Wind Farm – off North Devon Coast approx 35km distant.	DCO application submitted but withdrawn in November 2013.	Not considered.
Seventy six turbine Pen y Cymoedd windfarm near Neath.	Planning approved – construction 2014.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.

Projects	Stage in Planning Process	Preliminary Screening
Llynfi Afan Renewable Energy Park - fifteen turbine windfarm – on land 500m southwest of Cynnonville Port Talbot	Planning permission refused. Application was allowed on appeal on 27/08/2013.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Mynydd y Betws- fifteen turbine windfarm located on land to the east of Ammanford in Carmarthenshire	Granted planning consent 2009. Started operating April 2013.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Mynydd y Gwrhyd- windfarm in the Upper Amman and Swansea valleys	Approved on appeal 07/05/2009.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Swansea Port single wind turbine.	Operational	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Newlands Farm, single windturbine-Margam	Application submitted January 2013.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Kenfig Industrial Estate single wind turbine	Application submitted. Expected decision by Feb 2014.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Port Talbot Harbour redevelopment	Potential future activities/development. Status unknown.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Upgrading of the existing coastal defence of Aberavon West Promenade, Sandfields, Port Talbot	Completed August 2013.	Operational impacts associated with this development include the provision of new rocky surfaces along the upper shore within Swansea Bay which could be colonised by intertidal species which are dependent on hard substrate within Swansea Bay. This could result in potential cumulative/in-combination impacts in relation to the potential colonisation by non-native species. This has been assessed further in below.
Porthcawl regeneration scheme; includes Porthcawl Marina project and 19th century lighthouse restoration	Approved by BCBC. Timescale unknown.	This development is located approximately 20km and beyond a tidal excursion ²⁴ from the Project and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Tata Steel works – Internal power generation enhancement for Port Talbot steel works – installation of two new boilers and two new turbines housed in new power station building.	Application expected to be submitted 2014.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Underground coal gasification under Swansea Bay	License potentially to be extended.	Underground works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Underground coal gasification under Llanelli	Conditional Licence issued	Underground works outside of the marine environment and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.

²⁴ The nature of the tide is such that its movement is typically described as an almost closed ellipse. These tidal ellipses can be viewed as a package of water that will move to and fro over one tidal cycle, typically along a dominant axis, returning to almost the same position. As such, they can also be used to identify the maximum likely distance that water, or any material suspensions or solutions it may contain, might be tidally transported from a given location or area.

Projects	Stage in Planning Process	Preliminary Screening
Navigational dredging along Swansea (Tawe), Neath and Port Talbot Channels.	On-going.	During the construction phase there is potential for interaction between sediment plumes arising from the Project construction and sediment plumes created by maintenance dredging of the Swansea, Neath and Port Talbot approach channels. The cumulative/in-combination impacts associated with the plumes on the intertidal and subtidal benthic ecology receptors have been assessed further below.
Marina dredging - Monkston cruising and sailing club and Swansea Marina	On-going maintenance as required.	During the construction phase there is potential for interaction between sediment plumes arising from the Project construction and sediment plumes created by maintenance dredging of marinas. The cumulative/in-combination impacts associated with the plumes on the intertidal and subtidal benthic ecology receptors have been assessed further below.
Mumbles Oyster project: Plan to put 10,000 oysters on seabed off village of Oystermouth	Permission granted September 2013.	There will be no interaction between the sediment plumes arising from the Project construction and the oyster harvesting licence at Mumbles Ground and therefore there will be no cumulative/in-combination impact on this receptor.
Severn Barrage	Not within the foreseeable future	Not considered. See note in Chapter 2.
Swansea Barrage	Operational.	The Barrage is currently operational and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Cardiff Barrage	Operational.	The Barrage is currently operational and located more than 50km away and beyond a tidal excursion from the Project. Overall, therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Baglan Power station	Operational.	No cooling water discharge into the marine environment and therefore there will be no cumulative/in-combination impacts on intertidal & subtidal benthic ecology receptors.
Prenergy Biomass Power Station, Port Talbot – 350MW wood chip fuelled thermal generating station.	Granted condition approval by BERR on the 20 November 2007. While large scale construction has not been begun, a lawful start of development has occurred and as such the planning permission remains extant.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Abernedd Power Station was granted conditional approval by DECC on the 23 Feb 20011 for construction of a 870MW gas fired combined cycle gas turbine power plant	No lawful start has yet been made to this development.	Onshore works and therefore there will be no cumulative/in-combination impacts on intertidal and subtidal benthic ecology receptors.
Nobel banks aggregate extraction site	Ongoing.	Aggregate licence area is located approximately 35km and beyond a tidal excursion from the Project and therefore there will be no cumulative/in-combination impacts on intertidal & subtidal benthic ecology receptors.

Projects	Stage in Planning Process	Preliminary Screening
The Swansea Bay (Thomas Shellfish Limited) Mussel Fishery Order	Ongoing.	This Order confers a right of several fishery for mussels (<i>Mytilus edulis</i>) over an area of approximately 70 hectares in Swansea Bay for a period of 20 years. There will be no interaction between the sediment plumes arising from the Project construction and the Swansea Bay Mussel Fishery Order. The harvesting of mussels as a result of the Several Fishery Order will, however, act in-combination with the changes in habitat extent brought about by the Project. This has been assessed further below.
Ro-Ro Ferry – Swansea Port	Currently not operational	Not considered
Rhiannon Offshore Windfarm	Pre-application phase	Screened out
Burbo Bank Offshore Windfarm extension	Existing and extension sought 2013	Screened out
Tidal Energy Ltd Deltastream Installation Ramsey Sound	Consent secured. Installation 2014	Screened out
Seagen Skerries Tidal Stream Array	Consent secured. Installation 2014.	Screened out
Tidal Stream Energy Demonstration Array St David's Head, Pembrokeshire	Construction is planned to commence in 2017.	Screened out

8.6.0.3 Of the plans and projects listed in Table 8.9, only the following are considered likely to have potential cumulative and/or in-combination impacts on intertidal and subtidal benthic ecology receptors:

- i. construction of new RNLI Lifeboat Station, Mumbles;
- ii. navigational dredging at Tawe, Neath, Port Talbot and Bristol Channel;
- iii. marina dredging at Monkston Cruising and Sailing club and Swansea Marina;
- iv. upgrading of the existing coastal defence of Aberavon West Promenade, Sandfields, Port Talbot; and
- v. the Swansea Bay (Thomas Shellfish Limited) Mussel Fishery Order 2012.

8.6.0.4 Other activities that are considered in the assessment are existing shipping and recreational boating.

8.6.1 Construction phase

8.6.1.1 The key cumulative and/or in-combination impacts as a result of the potential interaction between the Project and other plans, project and activities during the construction phase are cumulative changes in suspended sediments.

Changes in suspended sediments

8.6.1.2 The Project will have generally have localised effects on SSC as a result of the dredging and filling of geotubes (Chapter 6 Coastal Processes). The modelling results predict that these temporary elevations in SSC will dissipate to background concentrations within a spring-neap tidal cycle on cessation of the works. Changes outside Swansea Bay are unlikely to be distinguished from the natural variability. Therefore, in physical terms, the plumes resulting from any dredging are expected have a minimal and local effect on SSC in the vicinity of the Project. SSC during dredge disposal are predicted to be within the level of variability found during existing disposal operations at the disposal ground.

The probability of plumes associated with the Project overlapping with ongoing maintenance dredging and aggregate extraction activities in Swansea Bay and the wider area together are considered to be low to medium. The magnitude associated with any potential overlap is considered to be small given the existing high natural variability in background levels of SSC. Exposure to change is consequently assessed as negligible to medium.

- 8.6.1.3 Based on a review undertaken in Section 8.5.2, the levels of sensitivity associated with all the intertidal and subtidal benthic ecology receptors in Swansea Bay (including intertidal sandflats, subtidal sands and gravels, rockpools, oysters and *Sabellaria* reefs) is considered to be none to low. Based on the levels of protection afforded to intertidal and subtidal benthic ecology receptors in Swansea Bay, the importance is considered to be low to high. Therefore, overall, the cumulative and/or in-combination impacts associated with changes in SSC are considered to be **insignificant** for unprotected features and **minor adverse significant** for protected features.

8.6.2 Operational phase

- 8.6.2.1 The key cumulative and/or in-combination impacts associated with the interaction between the Project and other plans, project and activities during the operational phase are the changes in habitat extent and the introduction of non-native species.

Changes in habitat extent

- 8.6.2.2 The development associated with the Swansea Bay (Thomas Shellfish Limited) Mussel Fishery Order 2012 located in the western part of Swansea Bay will result in the harvesting (i.e. removal) of mussels. The intertidal survey undertaken by ABPmer in 2013 found that the distribution of mussels was mainly restricted to two small areas of live mussel beds on the lower intertidal in this part of the Bay. There has been a loss in extent of the mussel beds in the Bay over the last decade which may have been due to increased competition for food and space as a result presence of the invasive non-native species of American slipper limpet, *Crepidula fornicata* (Section 8.4.5). The only other mussels found in the Bay are predominantly associated with artificial structures such as the existing eastern breakwater within the footprint of the Offshore Works. The Lagoon seawalls will result in a new hard surface which has the potential to provide alternative colonising habitat for mussels subject to suitable conditions (e.g. optimal food availability, competition for space and prevailing hydrodynamic conditions). The probability of this occurring is considered to be moderate to high and the magnitude is considered to be negligible to moderate depending on the scale and nature of any attachment and colonisation by mussels. The sensitivity of mussels to these changes is considered to be moderate and their importance is considered to be low given that it is a widespread species and is not afforded any nature conservation protection. Consequently, the overall cumulative and/or in-combination impact on mussels is considered to be **insignificant to minor beneficial significant**.

Introduction of non-native species

- 8.6.2.3 The new piles installed as part of the construction of the new RNLI lifeboat station and slipway and the upgrade to the existing coastal defence of Aberavon West Promenade will provide areas of new colonisation surface for subtidal and/or intertidal species in Swansea Bay which are dependent on hard substrate. Together with the Project, these changes could result in potential cumulative/in-combination impacts in relation to the

potential colonisation by non-native species. In addition, the existing shipping and recreational boating activity within the Bay will contribute to this impact pathway via the fouling of vessels' hulls and transport of species in ballast or bilge water. At present, vessels operating through the Port of Swansea very rarely undertake ballast water exchange in the vicinity of the Port and are required to maintain a ballast water management plan and a ballast water record book for inspection by the harbour authority and flag state (Section 8.5.6). Maintenance of hulls through best management practices applied during cleaning and the use of regulated protective coatings will minimise the number of fouling organisms present (Section 8.5.6).

- 8.6.2.4 The Project will provide a large area of new habitat for colonising in Swansea Bay, with other projects providing additional but smaller areas of habitat. In view of the above commitments and considerations, the probability of the introduction and spread of non-native species from other plans, project and activities together with the Project is considered to be medium to high and the magnitude is considered to be negligible to large depending on the scale and nature of any non-native species introduction. This results in a level of exposure that ranges from negligible to high. The sensitivity of the intertidal and subtidal benthic ecology receptors that would be affected will vary from none to high and their importance is considered to be low to high depending on the level of protection they are afforded. Consequently, the overall cumulative and/or in-combination impact on all intertidal and subtidal benthic ecology features associated with the potential introduction of non-native species is considered to be **insignificant to minor adverse significant** for unprotected features and **insignificant to major adverse significant** for protected features.
- 8.6.2.5 The residual impact of the potential introduction of non-native species on intertidal and subtidal ecology during operation of the Project can be limited further by following best practice guidelines (Section 8.7) in addition to following the guidelines on ballast water exchange and hull fouling described in Section 8.5.6). The application of these best practice mitigation measures will reduce the residual impact to protected intertidal and subtidal features to **insignificant to minor adverse significant**. In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon seawall during operation (see AEMP, Appendix 23.1).
- 8.6.2.6 Confidence in the cumulative/in-combination assessments are considered to be low to medium given the large number of variables associated with a cumulative assessment and uncertainties surrounding the specific impacts associated with each of the plans, projects and activities considered.

Overall cumulative and in-combination assessment

- 8.6.2.7 It is important to take account of the possible combined impacts of the Project on the intertidal and subtidal ecology receptors at the community and ecosystem level both for the area within the Lagoon and also the wider Swansea Bay area. Consideration should also been given to the linkages that exist between each of the receptors and the implications for ecological functioning.
- 8.6.2.8 There will be no significant changes in the abundance and productivity of water column phytoplankton within the lagoon given that water quality will not change significantly (Section 8.5.10) and the lagoon will be regularly flushed. Overall the magnitude of

change for the pelagic community is considered to be negligible and the impact **insignificant**.

- 8.6.2.9 Changes in the habitat extent and quality are likely to result in an overall reduction in biological diversity within the seabed sediments of the Lagoon and an increase in biological diversity of rocky shore ecology along the inner and outer edges of the Lagoon wall. In turn this is likely to introduce changes in competition for space and food resources and also changes in predator/prey relationships, which may lead to changes in the relative dominance of particular taxa. It is difficult to disentangle factors such as interspecific competition and predation from other physical and biological factors that will shape the structure of the invertebrate assemblage. It is likely that changes in the physical regime will be more visible in terms of their effects on invertebrate assemblages than factors such as competition and predation. Overall the magnitude of change for the ecological functioning of the benthic community is considered to be minor within the Lagoon and the impact of **minor adverse significance** at worst. Outside the Lagoon, the predicted changes are considered to result in a negligible magnitude of change to ecological functioning of the benthic community and the impact **insignificant**.
- 8.6.2.10 Confidence in the overall cumulative and in-combination assessment is considered to be low given that little or nothing is known about trophic level interactions and functional dependencies associated with intertidal and subtidal ecology, and the complexities of this unique system remains largely conceptual. Furthermore, the limited scientific understanding of the interplay between physical and chemical forcing factors and biological interactions makes it difficult to accurately predict changes in structure and function.
- 8.6.2.11 Given low confidence in this assessment, the magnitude and spatial extent of predicted effects on the full range of marine ecology receptors will necessarily require the development and implementation of a monitoring programme to assess actual changes relative to predictions. This programme will include monitoring of changes in habitat extent and habitat quality (see Section 8.9).

8.7 Mitigation

- 8.7.0.1 This section presents a review of measures that will be applied to monitor and mitigate potential, or known, adverse effects. It is recommended that an adaptive management approach is adopted. This is where available information as well as management processes can be reviewed in an iterative manner to improve future management. A carefully planned period for the management cycle needs to be defined prior to operation to present a clear timeframe after which both management advice and the management process will be reviewed and updated.

Habitat loss/change

- 8.7.0.2 It is recognised that direct loss of habitat can be mitigated by avoiding designated habitats at the project planning and design phase, making sure that appropriate weight is attached to designated sites; to protected species; habitats and other species of principal importance for the conservation of biodiversity.

Sabellaria translocation

- 8.7.0.3 Where sensitive habitats cannot be avoided mitigation methods have been investigated further. The feasibility of transplanting *Sabellaria alveolata* is being investigated for TLSB by SEACAMS to identify *Sabellaria* suitable for translocation, potential locations for placement and appropriate methods of translocation. A report by SEACAMS (Appendix 8.3, Volume 3) identifies that prior to construction works commencing, substantial blocks of *Sabellaria* reef could be moved to areas in Swansea Bay which are already colonised. If these are placed in the vicinity of the original location, then successful re-location is considered to be plausible, however, SEACAMS note that methods were still novel. Further, it was noted that if the worms themselves do not survive the move, the rigid tube structures were found to be generally robust and would survive at least for some weeks or even months, depending on the exposure to hydrodynamic forces. The worm-free tube aggregations would still allow colonisation by other invertebrates, and they would promote biodiversity. The tubes would also enable juvenile *Sabellaria* larvae to settle and rejuvenate the reef (Appendix 8.3, Volume 3). Therefore, the potential for the successful rehabilitation of this reef habitat exists although approaches are experimental.

Changes in suspended sediment concentrations (SSC) during construction

- 8.7.0.4 The adoption of published guidelines and best available practice techniques during construction activities will ensure that the spatial extent and concentration of suspended sediment created by the Project are limited. These will include adherence to relevant Construction Industry Research and Information Association (CIRIA) publications (e.g. Environmental Good Practice – Site Guide (C650)) and Pollution Prevention Guidance (PPG) (e.g. PPG5: Works and Maintenance In or Near Water). These will be contained in the Construction Environmental Management Plan (CEMP) produced for the Project as detailed in Chapter 4: Project Description

Discharges and spillages into the marine environment

- 8.7.0.5 Adoption of good practice will ensure that releases into the marine environment are minimised and contingency measures will be in place should such a spillage occur. Storage and use of materials that could potentially cause contamination (e.g. oil) is described in Chapter 18 Land Quality and Hydrogeology together with full details of best practice (e.g. storage within bunded areas) and mitigation measures (e.g. Spill Response Plan, use of booms, and spill kits). These measures are further detailed in the CEMP for the construction phase. The CEMP will include published guidelines and best available techniques that will be adhered to during the construction phase. Similarly for the operational phase, an OEMP will be produced. Further details of the CEMP and OEMP are given in Chapter 4.

Introduction of non-native species

- 8.7.0.6 Appropriate legislation and guidance as well as the implementation of best practice will limit the introduction and spread of non-native species. The GB NNNS website²⁵ provides links to specific biosecurity guidance and safety data sheets including; biosecurity for anglers; biosecurity for boat users; and biosecurity for submerged structures. These guidance notes set out simple instructions for disinfection measures

²⁵ <http://www.nonnativespecies.org//index.cfm?pageid=174>

to prevent the accidental transfer of invasive non-native species. This advice is relevant to a range of invasive non-native species, including: invasive shrimp *Dikerogammarus villosus*, carpet sea squirt *Didemnum vexillum*, leathery sea squirt *Styela clava*, slipper limpet *Crepidula fornicata*, zebra mussel *Dreissena polymorpha*, wakame *Undaria pinnatifida* and wireweed *Sargassum muticum*. The Green Blue²⁶ and Royal Yachting Association (RYA)²⁷ websites also provide Best Practice Advice for antifouling and non-native species.

8.7.0.7 The principles of good practice include:

- i. users of the marine environment (including boat users, harbour masters, aquaculture industry and construction industry) familiarising themselves with what non-native invasive species look like and how they can avoid spreading them;
- ii. for boats kept in the water permanently, hull fouling is the main means of transfer. Hulls should be cleaned regularly to avoid the risk of spreading and adequate antifouling applied;
- iii. thoroughly cleaning structures at the earliest opportunity before transfer, to allow the maximum period of drying. Structures should also be carefully inspected and, if necessary, thoroughly cleaned on arrival;
- iv. avoiding biofoul scrapings from entering the water;
- v. biofouling waste must be disposed of appropriately;
- vi. risks of acquiring invasive hitchhikers on boats increases the longer the boat is kept in the water. Considering only keeping the boat in the water when it is needed;
- vii. when leaving an anchorage, washing off both the anchor and chain before stowing;
- viii. draining all the water from boats before leaving a sailing site, including any caught in buckets or sails;
- ix. being aware of any additional signage or information on non-native species posted around water bodies;
- x. reporting any suspicions on invasive species sightings to the Food and Environment Research Agency (Defra); and
- xi. mitigating or managing or eradicating if non-native species are found.

8.7.0.8 In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon seawall during operation. Where non-native species are becoming/have become established mitigation, control and/or eradication may be needed. Mitigation measures may include establishing refuges for threatened species, where control may be achieved through containing a non-native species in a limited area, preventing or slowing its spread. Where necessary, localised populations of non-native species may need to be reduced or eradicated from particular areas (Defra, 2008). It should be noted, however, that once an invasive species has become widely established, full-scale eradication is possible or cost-effective in only a minority of cases (Millennium Ecosystem Assessment, 2005).

²⁶ http://www.thegreenblue.org.uk/boat_users/antifoul_and_invasive_species.aspx

²⁷ <http://www.rya.org.uk/infoadvice/planningenvironment/advice/Pages/AdviceonAntifouling.aspx>;
<http://www.rya.org.uk/infoadvice/planningenvironment/advice/Pages/AdviceonAlienSpecies.aspx>

8.8 Enhancement measures

Enhancing the Lagoon seawall

- 8.8.0.1 The Lagoon seawall itself is also being designed to promote and enhance the ecological diversity of the Bay through the use of bioblocks and rockpools which may promote the settlement of *Sabellaria* larvae and species associated with hydroid rockpools. A report by SEACAMS (Bertelli and Powell, 2013) investigated the ecological value that the Lagoon seawall could provide as a substrate for marine invertebrates. The report highlighted that artificial structures are often colonised by species that create their own habitat, such as kelp, mussels or honeycomb worms. As a consequence the artificial structure becomes host to secondary biogenic, reef-forming species which accelerate the development of a diverse algal and faunal community. The subtidal part of the structure can also enhance commercially important species such as lobsters and crabs. These benefits could also be extended to other commercial species such as mussels (*Mytilus edulis*), and native oysters (*Ostrea edulis*). In particular, the Lagoon seawall could attract settlement of *Sabellaria alveolata* offspring, which would assist in mitigating possible disturbances of the existing tube-worm reefs during the construction phase, or potential negative effects of a changed hydrodynamic regime. Artificial coastal defence structures have been found to provide settlement substrate similar to natural materials and were found to be colonised by large numbers of *S. alveolata* (Firth et al. 2013, Frost et al. 2004). Translocation of *Sabellaria* is also being investigated (see above).
- 8.8.0.2 The SEACAMS report reviewed previous work on the improvements of physical design of artificial coastal structures. This included the guidance report for the Environment Agency, as well as partner governmental bodies and developers, produced with information and advice regarding ecological enhancement in the planning, design and construction stages of hard coastal structures (Naylor et al. 2011). In order to maximise benefits of the Lagoon seawall for the environment, the following measures will be adopted for the Lagoon seawall (see AEMP, Appendix 23.1):
- i. avoiding smooth rock material: few organisms will colonise homogeneous surfaces and species colonisation rates will increase with surface roughness. Where possible, a mixture of hard and soft rock will be used. Soft rock (e.g. limestone) will erode quicker than hard rock (e.g. granite) which will create surface roughness and habitat for attachment of marine organisms. Furthermore, incorporating porous, calcite rich materials can provide habitat for other organisms, especially rock boring species. This can improve the habitat by increasing the roughness of the materials via bioerosion, for other species to then exploit;
 - ii. creating rock pools, pits and crevices: rock pools, pits and crevices increase water retention at low tide and provide refuges for intertidal organisms. These structures can enable some lower shore species to exist higher up the vertical gradient of the eulittoral zone and can sometimes support greater diversity than emergent substrata. These can be created by drill-coring into boulders and rock armour; and
 - iii. incorporating concepts such as shell bioreefs in or around the Lagoon seawall: bioreefs can provide protection from erosion and will enhance biodiversity.
- 8.8.0.3 SEACAMS Bangor have also been working on a project to develop a concrete 'bioblock' that can be used for ecological enhancements of revetments. The block is made of

concrete and has been designed to include pools of different depths on the top and holes and horizontal shelf like grooves on the sides to encourage marine life to grow. The project is ongoing and studies will be made to see if the structure is successful (AEMP, Appendix 23.1, Volume 3). In addition, studies at Swansea University in collaboration with the bioengineering company Salix, showed that shell filled mesh bags attract a diverse coastal fauna within a short period of time, and they have the potential of enhancing local biodiversity. These shell bioreefs can potentially be tailored to specific needs of an artificial structure to maximise the environmental benefits.

- 8.8.0.4 It should be noted that some of these enhancement methods are still experimental and, although these have been included as mitigation, their success at enhancing ecological diversity is yet to be proven. However, if left undisturbed, rocky habitats in Swansea Bay have the potential to develop into an unusually species rich community. Mumbles Pier is renowned for its diversity (Oakley, 2011), particularly bryozoans (sea mats). Species such as dahlia anemones, feather stars and lobster can be found among boulders and under overhangs. Monitoring of the Lagoon seawall would provide scope for educational and scientific studies that could obtain good baseline data for predicting the epibiota that colonise coastal structures in Swansea Bay. Artificial structures can also provide 'stepping stones' for the expansion and distribution non-native species and care must be taken to reduce and monitor this risk (see Section 8.9 below).

Enhancement of native oyster

- 8.8.0.5 Prior to construction, oyster dredge trawls of the Project area will be undertaken. It is proposed that any oysters identified will be translocated to the Centre for Sustainable Aquatic Research (CSAR) at Swansea University whilst construction works are ongoing, where their spawning behaviour and spat development will be monitored. In conjunction with SEACAMS, TLSB are also proposing an oyster enhancement programme as part of the operation of the Project to try and encourage the enhancement of the native oyster in Swansea Bay, with the aim of promoting biodiversity and ecosystem health. Current oyster stocks are low and the remaining population in Swansea Bay consists of relatively old individuals. Once the Project is in operation it is proposed that the spatfall of Swansea Bay oysters is maximised. Oyster which are collected prior to construction works commencing would be placed in spatting ponds inside the Lagoon. Spats from the oysters would be encouraged to settle on cultch. The juvenile oysters on cultch material could then be transferred to other appropriate areas inside the Lagoon to grow. The Lagoon offers shelter from wave energy which could optimise juvenile oyster growth. Young oysters could also be placed outside the Lagoon and performance, in terms of survival, growth and impact on biodiversity, monitored. Associated with the core aims, the program offers opportunities for other research on the biology and ecology of oysters and the ecosystem services of bivalve reefs. It should be noted that these enhancement measures are still being formalised. TLSB will work in conjunction with SEACAMS to develop these proposals (see AEMP, Appendix 23.1).
- 8.8.0.6 Translocations have been advocated as a beneficial way to restore degraded *O. edulis* stocks in the UK (Laing et al., 2005) and have had a high success rate in past restoration attempts. For instance, translocation of French stock to the Solent was credited with the establishment of new populations after heavy recruitment in both the host and adjacent areas. Temporary translocations, in the form of "spawner sanctuaries" have also been proposed as a method for increasing the recruitment of stocks and maximising the effective population size of small populations. Spawner sanctuaries are

protected areas such as cages, in which broodstock can be aggregated for the spawning season to increase the density of conspecifics and the likelihood of successful fertilisation (University Marine Biological Station Millport, 2007). Translocations have, however, led to the introduction of non-indigenous pest and disease species and care must be taken not to spread or introduce non natives to the area (see below). In recent years, numerous studies have been undertaken by NRW into the restoration potential of native oyster in Swansea Bay. In 2010 a series of seabed surveys were undertaken using underwater video equipment which mapped the potential oyster habitats around Mumbles and Swansea Bay (CCW, 2011). Having identified derelict oyster beds, made up of old oyster shells, with pebbles, sand and mussel shells, and very few live oysters a further NRW report investigated the practical methods of restoration of the native oyster population and associated fishery in South Wales (Woolmer *et al.* 2011). Further to this the Mumbles Oyster Company received permission in September 2013 from the Welsh Government for a plan to place 10,000 young oysters on a 70 acre historic bed off Oystermouth within Swansea Bay. The initial part of the project will see if juvenile Oysters (transported from Stranraer in Scotland) can survive in Swansea Bay, with the hope that the oysters placed on the seabed will then breed (BBC, 2013).

8.9 Monitoring

- 8.9.0.1 During construction and operation of the Project, monitoring of intertidal and subtidal receptors may be required to determine whether the development results in any changes in the distribution, extent and quality of marine ecology receptors. Monitoring that may be required, where appropriate, throughout the various phases of the Project are detailed in brief below with further details provided in the AEMP (Appendix 23.1, Volume 3). The results of the monitoring will be used to determine whether any additional mitigation measures are required in a process of adaptive management.

Pre-construction

- 8.9.0.2 As identified in Section 8.7 above, mitigation measures for oysters and Sabellaria will be commenced pre-construction.
- 8.9.0.3 An intertidal survey is proposed in the area around Mumbles Pier inside Swansea Bay. This area is recognised as particularly species-rich. Oakley (2011) recorded 91 species in the intertidal area since 2004. It appears that the habitat properties in the area are suitable for many invertebrate, algae and fish species. It is generally a rocky area with much artificial hard substrate, and some of the habitat features could be replicated within the design of the seawalls of the Project, particularly the outside of the lagoon wall.
- 8.9.0.4 Further subtidal benthic characterisation is proposed which will involve analysis of replicate samples collected during the surveys undertaken in 2013 (see Section 8.3.2.). It is proposed that 20 of the replicate samples collected in 2013 will be analysed for infauna which includes a control site that is out of the influence of the Project.

Construction

- 8.9.0.5 Intertidal surveys examining the colonisation of the seawalls are proposed to commence in the construction phase. It is proposed that this will also involve identification of the presence of invasive species. Intertidal surveys are also proposed within the lagoon footprint for changes in sediment composition and benthic fauna.

The translocated reef blocks would be assessed for the survival of *Sabellaria* and the vitality compared to species present in the non-translocated areas of the reef. Spawning behaviour and spat development of translocated oysters would be undertaken at CSAR at Swansea University.

Operation

- 8.9.0.6 Monitoring of both subtidal and intertidal habitats on the seawalls is proposed following construction of the Project. This would also involve checking for the presence of invasive species and the colonisation of the habitat by *Sabellaria*.
- 8.9.0.7 The mitigation measures for oysters will be progressed in that oysters stored in CSAR will be relocated to the spatting poinds constructed as part of the Project. Subsequently areas inside and outside the lagoon will be stocked.
- 8.9.0.8 Intertidal and subtidal surveys are also proposed. For the intertidal area, the areas covered in the baseline study carried out in 2013 (see Section 8.3.2) would be surveyed. Subtidal surveys are proposed at the 20 sites where further replicate samples were analysed in the Pre-construction phase. Samples would be analysed for Partical Size Analysis, metals and infauna.
- 8.9.0.9 It is proposed that phytoplankton and zooplankton abundance is monitored inside and outside the lagoon during the operation of the lagoon.

8.10 Conclusion

- 8.10.0.1 This chapter has identified a number of pathways along which potential impacts to marine ecology receptors arising from the Project could occur. Table 8.10 summarises the impact significance, suggested mitigation and monitoring, residual impact and confidence for each of the pathways in construction and operation based on the findings presented in Sections 8.5 and 8.6. The main impacts on marine ecology arising from the Project relate to protected features e.g. *Sabellaria*, hydroid rockpools, intertidal mudflats and sandflats and subtidal sands and gravels. The pathways with the highest impacts on these protected features are the redeposition of suspended sediments during construction, change in habitat extent and suitability, change in suspended sediment concentrations and the potential spread and introduction of non-native species during operation. Mitigation measures have been identified in order to reduce the residual impacts to acceptable levels.

Table 8.10 Summary of potential impacts

Project Stage	Pathway	Receptor	Impact Significance	Mitigation	Residual Impact	Confidence
Construction Phase	Changes in suspended sediment concentrations	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
		Subtidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
	Release of contaminants associated with the dispersion of suspended sediments	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Insignificant	Not required	Insignificant	
		Subtidal ecology	Insignificant	Not required	Insignificant	
	Re-deposition of suspended sediment	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Insignificant to minor adverse (unprotected features)	Not required (unprotected features)	Insignificant to minor adverse (unprotected features)	
			Moderate adverse (protected features)	Mitigation measures include; translocation of Sabellaria reef and opportunities to encourage the settlement of Sabellaria larvae and enhancing the lagoon wall with bioblocks and rockpools to promote ecological diversity.	Minor adverse (protected features)	
		Subtidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
			Insignificant to minor adverse	Not required	Insignificant to minor adverse	
	Discharges and accidental spillages	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
		Subtidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	

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Project Stage	Pathway	Receptor	Impact Significance	Mitigation	Residual Impact	Confidence
	Introduction of non-native species	Plankton	Insignificant	Not required	Insignificant	Medium
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
		Subtidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
	Changes in habitat suitability	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant to minor beneficial	Not required	Insignificant to minor beneficial	
		Intertidal ecology	Insignificant (unprotected features)	Not required	Insignificant (unprotected features)	
			Minor adverse (protected features)	Not required	Minor adverse (protected features)	
		Subtidal ecology	Insignificant (unprotected features)	Not required	Insignificant (unprotected features)	
			Minor adverse (protected features)	Not required	Minor adverse (protected features)	
	Cumulative/in-combination: Suspended Sediments	All	Insignificant to minor adverse	Not required	Insignificant to minor adverse	Low to medium
Operational Phase	Change in habitat extent	Plankton	Insignificant to minor adverse	Not required	Insignificant to minor adverse	High
		Macroalgae	Insignificant to minor beneficial	Not required	Insignificant to minor beneficial	
		Intertidal ecology	Minor adverse (unprotected features)	Not required (unprotected features)	Minor adverse (unprotected features)	

Tidal Lagoon Swansea Bay plc

Project Stage	Pathway	Receptor	Impact Significance	Mitigation	Residual Impact	Confidence
			Major adverse (protected features)	Mitigation measures include; translocation of <i>Sabellaria</i> reef and opportunities to encourage the settlement of <i>Sabellaria</i> larvae and enhancing the lagoon wall with bioblocks and rockpools to promote ecological diversity as a biodiversity offsetting measure. In addition, the extent and quality of protected intertidal habitat features will be monitored.	Minor to moderate adverse (protected features)	
		Subtidal ecology	Minor adverse (unprotected features)	Not required (unprotected features)	Minor adverse (unprotected features)	
			Major adverse (protected features)	Opportunities include promote and enhancing ecological diversity through the design of the lagoon wall, providing a biodiversity offsetting measure for losses; and introducing oyster and restoring historic oyster bed habitat as part of the operation of the project.	Minor to moderate adverse (protected features)	
	Change in habitat suitability	Plankton	Insignificant	Not required	Insignificant	Medium to high
		Macroalgae	Insignificant	Not required	Insignificant	
		Intertidal ecology	Minor adverse (unprotected features)	Not required (unprotected features)	Minor adverse (unprotected features)	
			Major adverse (protected features)	Mitigation measures include; translocation of <i>Sabellaria</i> reef and opportunities to encourage the settlement of <i>Sabellaria</i> larvae and enhancing the lagoon wall with bioblocks and rockpools to promote ecological diversity as a biodiversity offsetting measure. In addition, the extent and quality of protected intertidal habitat features will be monitored to determine the actual effects of the project.	Moderate adverse (protected features)	
		Subtidal ecology	Minor adverse (unprotected features)	Not required (unprotected features)	Minor adverse (unprotected features)	

Project Stage	Pathway	Receptor	Impact Significance	Mitigation	Residual Impact	Confidence	
			Major adverse (protected features)	Opportunities include promote and enhancing ecological diversity through the design of the lagoon wall, providing a biodiversity offsetting measure for losses; and introducing oyster and restoring historic oyster bed habitat as part of the operation of the project.	Moderate adverse (protected features)		
	Changes in water quality	Plankton	Insignificant	Not required	Insignificant	Medium	
		Macroalgae	Insignificant	Not required	Insignificant		
		Intertidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse		
		Subtidal ecology	Insignificant to minor adverse	Not required	Insignificant to minor adverse		
	Changes in suspended sediment concentrations	Plankton	Insignificant	Not required	Insignificant	Medium to high	
		Macroalgae	Insignificant	Not required	Insignificant		
		Intertidal ecology	Insignificant (unprotected features)	Not required	Insignificant (unprotected features)		
			Minor adverse (protected features)	Not required	Minor adverse (protected features)		
		Subtidal ecology	Insignificant (unprotected features)	Not required	Insignificant (unprotected features)		
			Minor adverse (protected features)	Not required	Minor adverse (protected features)		
	Damage/ obstruction to planktonic species	Plankton	Insignificant	Not required		Insignificant	Low
		Macroalgae	Not assessed				
		Intertidal ecology	Not assessed				
		Subtidal ecology	Insignificant	Not required		Insignificant	
	Changes in biological interactions	Plankton	Insignificant	Not required		Insignificant	Low
		Macroalgae	Insignificant	Not required		Insignificant	
		Intertidal ecology	Insignificant	Not required		Insignificant	

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Project Stage	Pathway	Receptor	Impact Significance	Mitigation	Residual Impact	Confidence
		Subtidal ecology	Insignificant	Not required	Insignificant	
	Introduction on non-native species	Plankton	Not assessed			Medium
		Macroalgae	Insignificant to minor adverse	Not required	Insignificant to minor adverse	
		Intertidal ecology	Insignificant to moderate adverse	The application of appropriate legislation and guidance as well as best practice mitigation measures.	Insignificant to minor adverse	
		Subtidal ecology	Insignificant to moderate adverse	In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon wall during operation.	Insignificant to minor adverse	
	Cumulative/in-combination: Habitat extent	Mussels	Insignificant to minor beneficial	Not required	Insignificant to minor beneficial	Low to medium
	Cumulative/in-combination: Non-native species	All	Insignificant to major adverse	The application of appropriate legislation and guidance as well as best practice mitigation measures. In addition, the extent and quality of non-native species will be monitored to determine the composition and distribution of any non-native species on the Lagoon wall during operation.	Insignificant to minor adverse	Low to medium

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