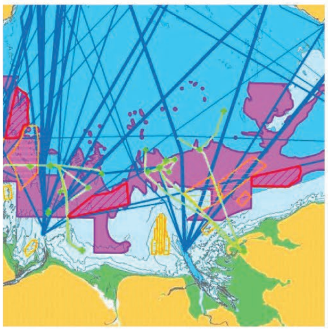
Welsh Government

Sustainable Management of Marine Natural Resources

Work Package 1

July 2019




Innovative Thinking - Sustainable Solutions

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		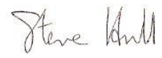

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Non-Technical Summary

The draft Welsh National Marine Plan (WNMP) identifies a number of sector-specific Strategic Resource Areas (SRAs) which are defined spatial areas where, based on an analysis of existing high-level evidence, it is considered that there are marine natural resources suitable and appropriate for sustainable exploitation. Welsh Government was awarded a European Maritime and Fisheries Fund (EMFF) grant to develop, and make available, a targeted environmental evidence base on the marine environment to support implementation of marine planning in Wales.

The three activities selected as a priority for this project (referred to as focus activities) include aquaculture, tidal stream energy and wave energy, identified on the basis of:

- Being of strategic importance; but
- Lacking an existing easily accessible, applied, fit for purpose and coherently structured in-depth evidence base; and
- The collation and interpretation of in-depth datasets and new evidence being achievable within the scope and budget of the EMFF project.

The main objectives of this project are to address the need for fit for purpose (synthesised, interpreted, quality assured and refined) data and knowledge to support marine environmental protection and sustainable use of aquaculture, tidal (stream) energy and wave energy resources.

The overall project, as defined in the EMFF grant, is divided into two Work Packages (WPs):

- **Work Package 1 (WP1)** – Consolidating the marine environmental evidence base for Wales. This WP will identify areas for investigation; identify knowledge needs; gather, collate and process available data; and identify key knowledge gaps; and
- **Work Package 2 (WP2)** – Enhancing and applying marine evidence to support sustainable development. It is currently envisaged that this WP will collect data; produce and disseminate guidance; and produce constraints and opportunity maps for sustainable development and activities within target SRAs.

This report provides the outputs from WP1, identifying the key issues, constraints and opportunities for the three focus activities and highlighting the current data/evidence available, while also considering gaps and how these could be filled in future phases of the project. This report is supported by several other deliverables which together form WP1:

- Evidence database;
- Guidance spreadsheet;
- ArcGIS geodatabase; and
- Welsh Marine Planning Portal review.

The key objectives of this report were:

- Identification and collation of datasets in relation to draft SRAs and wider Welsh marine area;
- Quality assurance and confidence assessment of available datasets;
- Highlighting key datasets available (e.g. physical, chemical, biological, pressures etc.);
- Identification of spatial data gaps in relation to the distribution, abundance and function of key features specific for draft SRAs but also the wider Welsh marine area;

- Consideration of specific impact pathways from focus activities, to inform the overall gap analysis, including exposure and sensitivity of a feature to resulting pressures, through a review of available evidence;
- Further considerations for sustainable development; and
- Recommendations on how to improve the environmental evidence base to support the growth of focus activities.

The data collation exercise identified existing spatial data for key features for each of the focus activities and identified existing marine evidence in Welsh waters. A standardised quality assurance and confidence assessment was applied to the data. In addition, data of wider and generic relevance to the project and marine developments was also collated, interpreted and quality assured, as appropriate.

Evidence sources for informing site selection and providing contextual baseline information for the focus activities resulted in the creation of an evidence database and geodatabase containing 432 potentially relevant datasets for the three focus activities. Of these, 214 datasets were assessed as high quality with high confidence (high scoring data). High scoring data were mapped to assess the spatial coverage and identify key data gaps. Draft SRAs for the focus activities and designated conservation sites were overlaid on to the maps to help assess data availability within the areas. Key data gaps were identified in relation to baseline characterisation of biological features. Physical and chemical data were also sparse.

Concerns were expressed by stakeholders over the consenting of tidal stream, wave energy and aquaculture sectors due to uncertainties in the potential effects on marine features. Subsequently, evidence on specific impact pathways to help identify additional evidence gaps over and above the spatial data gaps were recognised. In many cases, the uncertainties and limitations of evidence surrounding the new technologies, leading to a 'survey, deploy, monitor' policy as a condition imposed during the consenting of these focus activities. Encouraging evidence and data collected to be publicly available will allow emerging industries to better understand the potential issues, while ensuring consenting risk is kept to a minimum and conditions are proportionate as the sectors evolve.

A range of tools and guidance were identified to help developers understand the consenting and assessment process for the focus activities. Recommended tools included IMPACT and the Management measures tool for tidal stream and wave energy; NewDEPOMOD and SMILE for finfish and shellfish aquaculture respectively. The Marine Energy Wales and ORJIP websites provide consenting guidance or links to consenting documents in relation to UK tidal and wave projects. A range of generic guidance is available for aquaculture and a consenting toolbox has now been developed by CEFAS that covers Welsh waters.

In relation to achieving sustainable development of the focus activities, consideration was also given to the supporting infrastructure, cumulative impacts, consenting process and future proofing of SRAs.

The study identified a number of key recommendations for data that would aid site selection and, more specifically, baseline characterisation. These included:

- Benthic habitat (such as Section 7 habitats) condition and extent data;
- Up-to-date marine mammal and seabird distribution datasets covering all Welsh waters;
- Basking shark distribution dataset; and
- Marine non-native species 'hot-spot' data.

To fill these data gaps, recommendations for future work encompassed broadscale benthic habitat surveys to inform presence, condition and extent of sensitive features within targeted SRA locations; aerial surveys of seabird and marine mammal distribution in Welsh waters. A series of case examples were provided which suggest options for data collection that would benefit the three focus activities.

Contents

Appendices

Image

Tables

Figures

1 Introduction

There is increasing recognition of the need to better manage marine activity both to ensure that marine environmental objectives are met but also to enable sustainable blue growth (economic growth based on several maritime sectors). Marine spatial planning is important for addressing increased competition for space between marine activities and for seeking to ensure that the capacity of the marine environment is not exceeded.

Within the United Kingdom (UK), the Marine and Coastal Access Act (MCAA) 2009 established a statutory system of marine planning for UK waters, including waters around Wales. At a wider European Union (EU) level, the Maritime Spatial Planning (MSP) Directive (2014/89/EU) established a statutory framework for maritime spatial planning across all of EU waters with the objective of developing marine plans covering the entirety of EU waters by 2021. MSP is a key component of the EU's Integrated Maritime Policy (IMP) which seeks to provide a more coherent approach to maritime issues.

Under the MCAA, the UK Marine Policy Statement (MPS; HM Government, 2011) provides the high-level context for marine planning and the framework for preparing national and regional marine plans, including the Welsh National Marine Plan (WNMP). The MPS sets out five High Level Marine Objectives (HLMOs) which have guided the development of the WNMP:

- Achieving a sustainable marine economy;
- Ensuring a strong healthy and just society;
- Living within environmental limits;
- Promoting good governance; and
- Using sound science responsibly.

The WNMP has now been drafted and was subject to a period of public consultation (7 December 2017 to 29 March 2018). Following consultation, the draft WNMP is now in the process of being updated in preparation for ministerial sign off. Guided by the UK Marine Policy Statement, the draft WNMP has a distinct Welsh context and applies the principles of the Well-being of Future Generations (Wales) Act 2015 and Environment (Wales) Act 2016.

Sustainable management of marine and coastal natural resources is central to the WNMP objectives and the Sustainable Management of Marine Natural Resources (SMMNR) project (this project) is intended to increase the sustainable utilisation of the marine environment. The policy rationale set out in the WNMP is to:

- Ensure the sustainable management of natural resources by taking account of cumulative effects of human pressures;
- Encourage economically productive activities in areas of good opportunity;
- Support the sustainable development of marine renewable energy resources;
- Provide space to support existing and future sustainable co-location of different activities and reducing avoidable displacement activities;
- Support the achievement and maintenance of Good Environmental Status (GES);
- Protect and enhance marine biodiversity including Marine Protected Areas (MPAs); and
- Enhance the resilience of marine ecosystems.

The draft WNMP identifies several sector-specific Strategic Resource Areas (SRAs). These are defined spatial areas where, based on an analysis of existing high-level evidence, it is considered that potentially viable marine natural resources exist which are suitable for sustainable exploitation. For each SRA there are draft WNMP policies that:

- Encourage sustainable projects to be proposed for the supported sector;
- Encourage further evidence collection and interpretation to help identify opportunities and constraints for development; and
- Require proposals from other activities (i.e. other than the supported sector) to demonstrate that they will not have an adverse effect upon future use by the supported sector.

The draft WNMP also includes policies in relation to the protection and enhancement of the marine environment (living within environmental limits) as well as achieving sustainable blue growth.

SRAs, as they have currently been defined, take account of sectoral constraints on development but do not fully address potential environmental issues associated with different types of developments and activities in these areas. Consequently, there is a need to better understand environmental constraints and opportunities, particularly where they overlap with areas of higher environmental sensitivity such as MPAs. There is also a need to assess the most sustainable opportunities for development and use of marine natural resources within these SRAs, at a local level, particularly given that there is a significant overlap with MPAs. **The key purpose of this study is to initiate and progress work to identify and meet these evidence requirements.**

Welsh Government has been awarded a European Maritime and Fisheries Fund (EMFF) grant to develop, and make available, a targeted environmental evidence base on the marine environment to support implementation of marine planning in Wales. The three activities that have been selected as a priority for this project (focus activities) encompass:

- Tidal stream energy;
- Wave energy; and
- Aquaculture.

These have been identified based on:

- Being of strategic importance, but lacking an existing easily accessible, applied, fit for purpose and coherently structured in-depth evidence base; and
- The collation and interpretation of in-depth datasets and new evidence being achievable within the scope and budget of the EMFF project.

The main objectives of this project were to address the need for fit for purpose (synthesised, interpreted, quality assured and refined) data and knowledge to support marine environmental protection and sustainable use of tidal energy, wave energy and aquaculture resources. Stakeholder collaboration has been central to delivery thereby strengthening outputs and stakeholder buy-in to the project. This has included generating as much consensus as possible between all stakeholders (including developers and regulators) about the outputs to enable a shared understanding of the constraints and opportunities relating to these areas.

The following figures (Figure 1 to Figure 3) depict the boundaries of draft SRAs for each of the three focus activities.

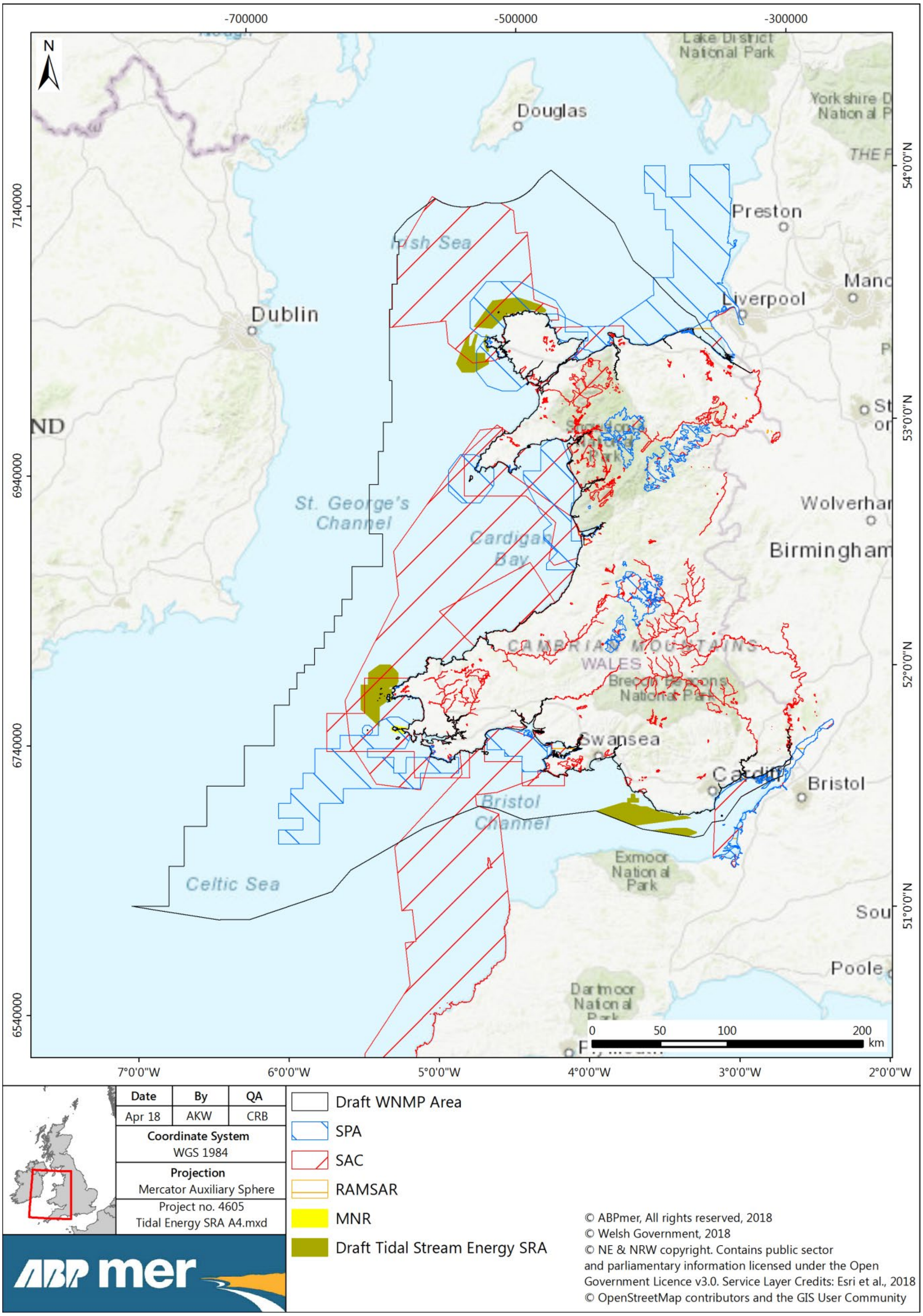


Figure 1. **Tidal stream energy draft SRA**

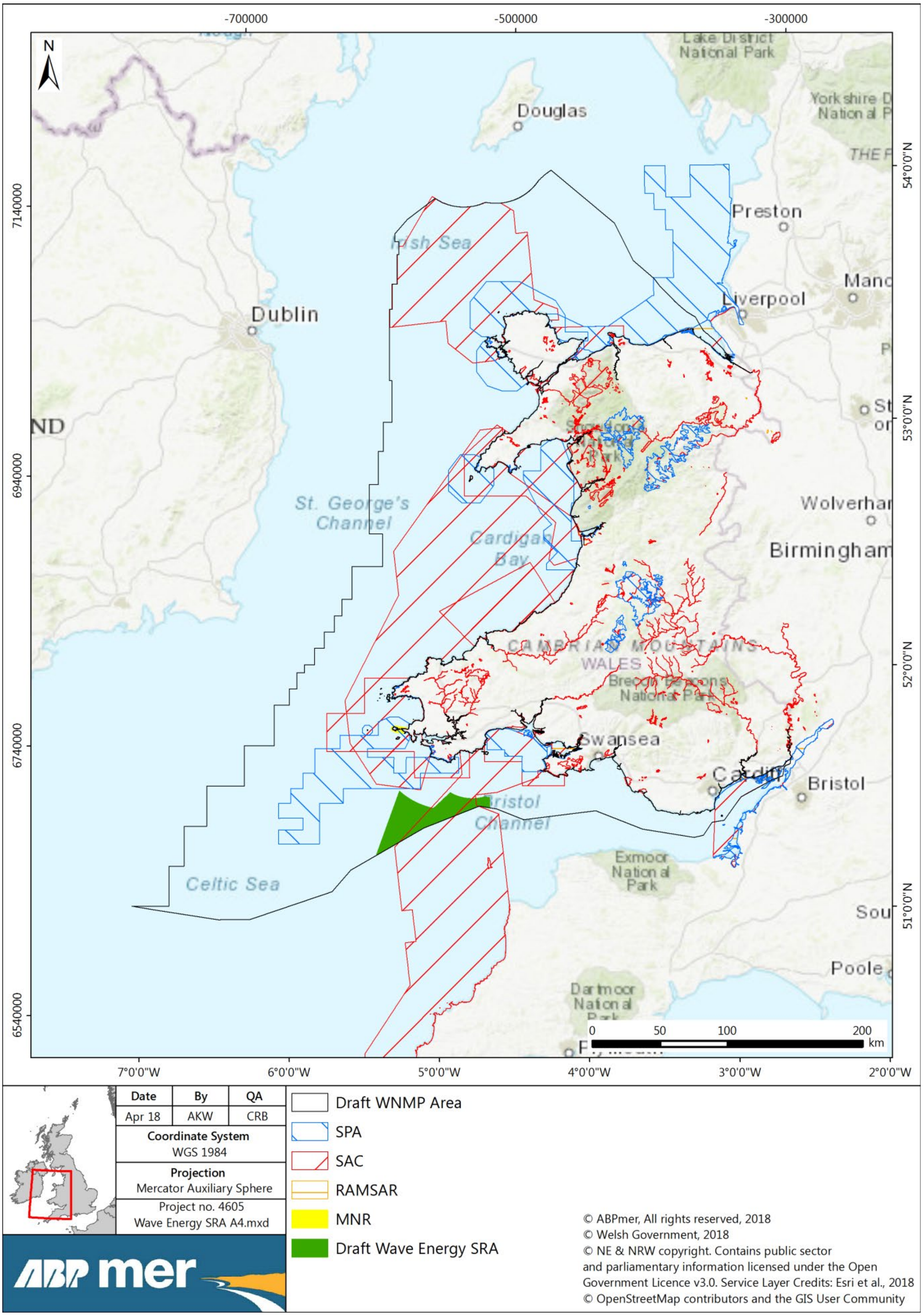


Figure 2. Wave energy draft SRA

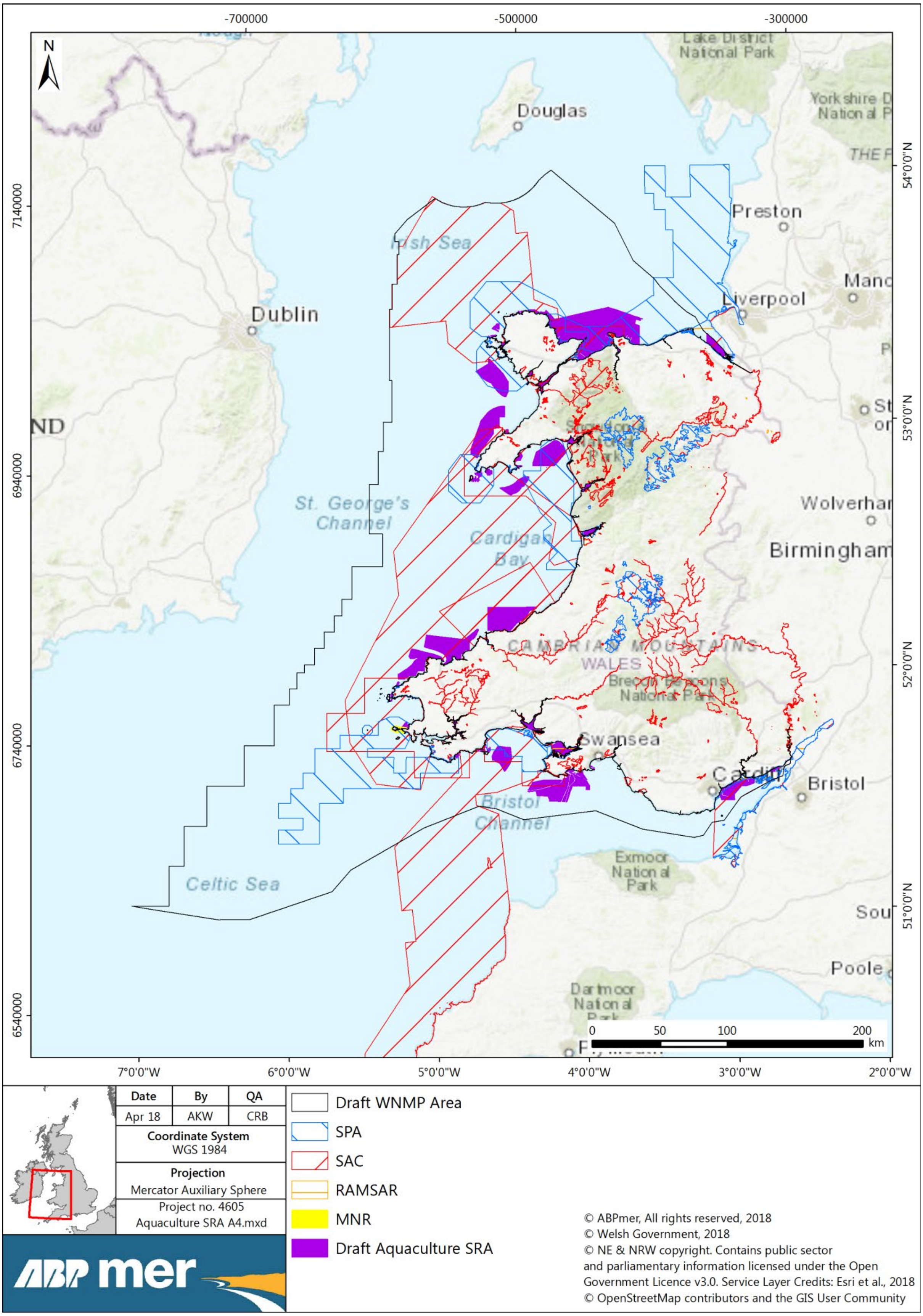


Figure 3. Aquaculture draft SRA

1.1 Overall approach

The Sustainable Management of Marine Natural Resources project is intended to increase understanding of the marine environment and to develop plans that provide sufficient local specificity and data against which benefits of marine planning can be understood and demonstrated. The project will do this by gathering new evidence and also, collating, analysing and interpreting environmental (biological, chemical and physical) datasets that relate to the draft SRAs (Figure 1 to Figure 3) and thus the focus activities, addressing key knowledge gaps in marine planning such as the carrying capacity (i.e. environmental limits) of each SRA for the intended activity and specific areas of particular sensitivity or opportunity at the local scale.

The project is divided into two Work Packages (WPs):

- **Work Package 1 (WP1)** – Consolidating the marine environmental evidence base for Wales. This WP will identify areas for investigation; identify knowledge needs; gather, collate and process available data; and identify key knowledge gaps; and
- **Work Package 2 (WP2)** – Enhancing and applying marine evidence to support sustainable development. This WP will collect data; produce and disseminate guidance; and produce constraints and opportunity maps for sustainable development and activities within draft SRAs. Recommendations will also be provided on the refinement of SRA boundaries where appropriate.

This report is supported by a number of work outputs which together form WP1:

- Inception report:
  - Detailed work plan;
  - Stakeholder needs and consultation.
- Marine planning portal recommendations review;
- Final report and evidence database:
  - Data collation;
  - Gap analysis;
  - Evidence database and ArcGIS geodatabase;
  - Review of specific impact pathways;
  - Spreadsheets of references and marine planning tools; and
  - Recommendations for future data and evidence requirements.

The interrelationships between these work package elements are illustrated within Figure 4.

The inception report was finalised in August 2018 (ABPmer, 2018a) following stakeholder engagement events (Appendix A). The marine planning portal review is a standalone document (ABPmer, 2018b) and submitted as part of the overall WP1. The final report (this report) encompasses several deliverables either contained within this document or provided as separate products to support the overall package of work (e.g. ArcGIS geodatabase).

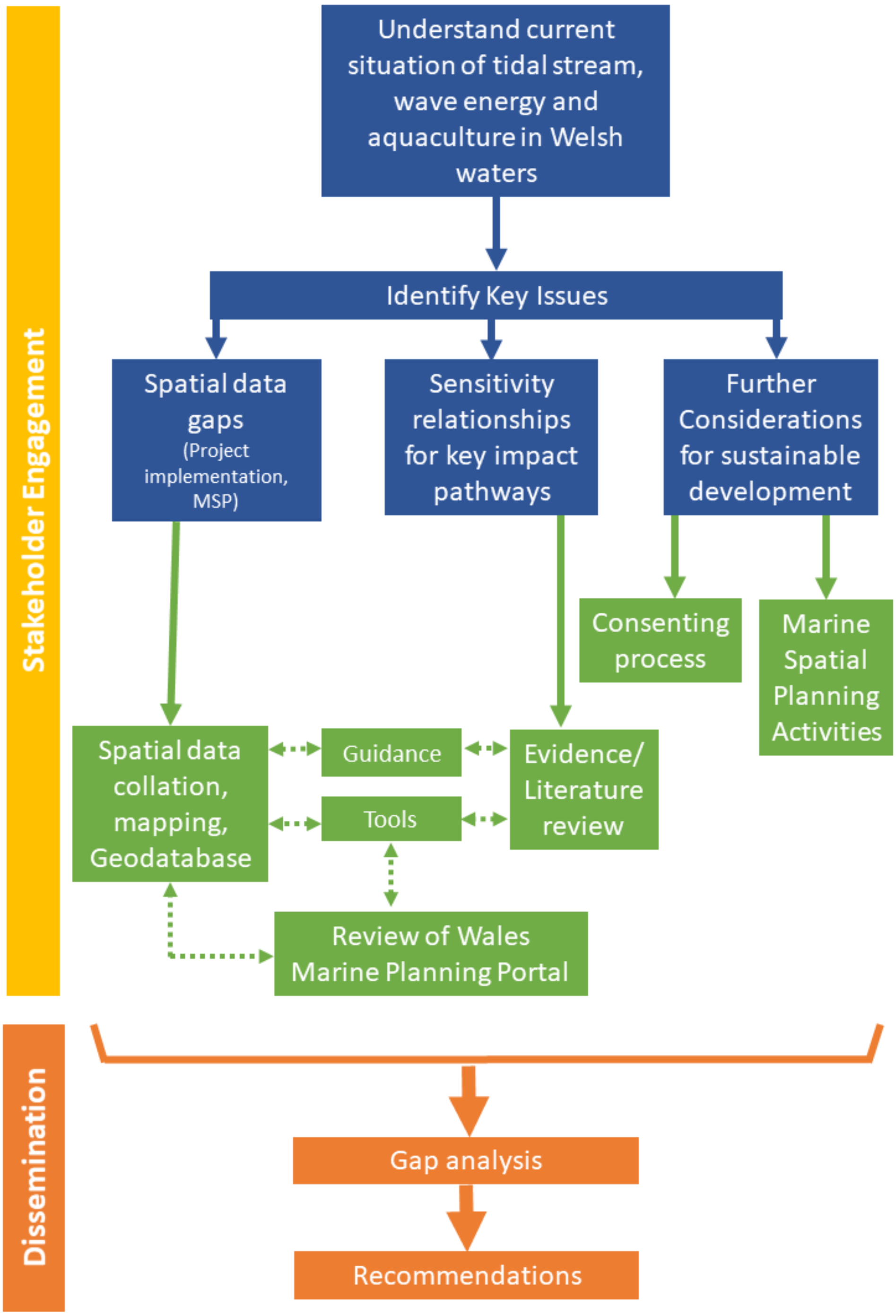


Figure 4. Schematic of work flow

1.2 Objectives

The key objectives of this report are:

- Identification and collation of datasets in relation to draft SRAs and wider Welsh marine area;
- Quality assurance and confidence assessment of available datasets;
- Highlighting key datasets available (e.g. physical, chemical, biological, pressures etc.);

- Identification of spatial data gaps in relation to the distribution, abundance and function of key features specific for draft SRAs but also the wider Welsh marine area;
- Consideration of specific impact pathways from focus activities, to inform the overall gap analysis, including exposure and sensitivity of a feature to resulting pressures, through a review of available evidence;
- Further considerations for sustainable development; and
- Recommendations on how to improve the environmental evidence base to support the growth of focus activities.

1.3 Report structure

This report is structured into the following sections:

- Introduction – this section.
- Background – information on focus activities.
- Data collation – methodology, quality assurance, key data requirements and availability, data gaps and review.
- Specific impact pathways – identifying data and evidence gaps to inform assessment of identified impact pathways.
- Further considerations – supporting infrastructure, cumulative impacts, consenting process and future proofing of SRAs
- Recommendations including:
    - Further data requirements;
    - Evidence to understand specific impact pathways;
    - High-level constraints to draft SRAs;
    - Consenting approach, guidance and tools; and
    - Future data collection – marine surveys and case examples.

A number of outputs support this report and are deliverables encompassed by WP1 (see above). These are either appended to this report (e.g. spreadsheet of tools; spreadsheet of references); embedded within this report (GIS maps) or are provided as part of the final package of work (evidence database (see Appendix I.1), ArcGIS geodatabase (see Appendix I.2), guidance spreadsheet (see Appendix I.3) and marine planning portal review (ABPmer, 2018b)).

All relevant data identified through the data collation exercise is presented in an evidence database and geodatabase (ArcGIS), structured for each of the three focus activities, in a format which has consistent data layers.

The evidence database includes data type, source, age, quality assessment, confidence and signposting to relevant data held but not currently accessible. Where key information exists in the form of peer-reviewed or grey literature this has also been provided if appropriate; however, a detailed literature review does not form part of this work package. The evidence database is provided as an Excel workbook.

The geodatabase provides the metadata for all data processed and relevant to the focus activities and provided as an ArcGIS package (Appendix I.2).

2 Background Information

This section considers each of the three focus activities, providing a description of each activity (Section 2.1), a summary of the consenting process (Section 2.2) and a review of key issues including stakeholder requirements and how they can be addressed (Section 2.3). Information has been gathered from the UK MPS (HM Government, 2011), the draft WNMP, other relevant published reports, online searches for current sector activity, recent sector specific conferences (e.g. Aquaculture Common Issues Group (ACIG) meeting, 18 April 2018 and Marine Energy Wales, 19 April 2018) and through discussion at a workshop held on 20 April 2018 in Cardiff. Over 70 stakeholders were invited to attend the workshop, including developers, decision makers, regulators and advisors (a list of organisations in attendance is provided in Appendix B). The workshop identified key issues, constraints and opportunities for the three focus activities, highlighted available data/evidence, while also considering gaps and how these could be filled in the future.

Since the workshop, further updates have been made to align with new data/information and the outcomes of additional stakeholder meetings relevant to the focus activities e.g. the Shellfish Centre workshop held on 4th December 2018 in Menai Bridge.

The EMFF project 'SMNRR' (this project) acknowledges that planning and consenting for marine activities is a complex process involving numerous parties and multiple environmental, social and economic factors. Such complexity inevitably creates many issues and challenges in securing consent for sustainable activity. Different stakeholders have varying expectations and experiences of the processes and thus differing views of issues and solutions. This project is therefore seeking to reflect the diversity of views although with an emphasis on addressing key issues identified in the project specification, namely - to address the need for fit for purpose (synthesised, interpreted, quality assured and refined) data and knowledge to support marine environmental protection and sustainable use of tidal energy, wave energy and aquaculture resources. Ultimately there is a need to try and achieve (as far as possible) a shared understanding of all the key opportunities and constraints with all stakeholders so that the benefits and risks of developing in these areas can be shared as widely as possible.

2.1 Description of each activity

2.1.1 Tidal stream energy

Definition

Electricity can be generated from areas of suitable tidal stream resources using tidal energy generators. Tidal stream technologies specifically utilise the flow of water generated by tidal currents.

For context, it should be noted that tidal range technologies (not considered as part of this project) rely on the static pressure differential created by the rise and fall of tides (e.g. barrages and lagoons). Suitable locations for the deployment of tidal stream energy generators are currently limited by the technology to areas of strong tidal currents.

Overview of existing activity

Tidal energy generation is an emerging industry within Welsh waters, and there are currently no commercial scale tidal stream energy arrays installed. The draft WNMP has identified that that there is a substantial tidal stream energy resource at several locations within Welsh inshore waters, mainly where water flows are restricted, such as within narrow channels and around coastal headlands where the constriction of flow accelerates the tidal current (Roche *et al*. 2016). Specifically, the Marine Renewable Energy Strategic Framework (Welsh Assembly Government, 2011) highlighted practical opportunities to use marine energy resources and identified a scenario which has the potential to secure 6.4 gigawatts (GW) through tidal stream energy (and wave energy) development. It is envisaged that tidal stream energy technologies will be focussed on small scale demonstration devices in prime locations (including demonstration zones) over the next 5 to 10 years, with potential for subsequent larger scale deployment within wider resource areas, dependent on achieving significant reductions in the cost of energy operation.

The West Anglesey Tidal Demonstration Zone (Morlais Demonstration Zone, off Anglesey, North Wales), managed by Menter Môn, is one of several demonstration zones around the UK which have been leased out by The Crown Estate in a bid to encourage and accelerate technology development. Menter Môn, the manager of the Morlais tidal energy project, has been awarded £4.5 million of EU and Welsh government funds to further develop the zone. This zone was identified because it offers appropriate tidal stream energy potential as well as access to necessary infrastructure, including ports and the electricity grid (Marine Energy Pembrokeshire, 2015). It is envisaged that the fully consented area of seabed will be able to support at least 20 MW of grid connection capacity, but with potential for around 190 MW, to enable developers to deploy and test multiple tidal energy technologies.

In April 2017, tidal stream energy developer Minesto UK Ltd received a marine licence from Natural Resources Wales (NRW) to install a 0.5 megawatt (MW) Deep Green demonstrator (DG500) device at Holyhead Deep, located immediately to the west of the West Anglesey Tidal Demonstration Zone. In spring 2018, Minesto installed and commissioned the site infrastructure which included the seabed foundation, tether, umbilical and a buoy within Holyhead Deep, 6 km off the coast of Anglesey. Supported by EU funding through the Welsh government, the project generated electricity for the first time in early October 2018. Following successful deployment and testing of the DG500, Minesto has decided to resume offshore operations of its tidal energy system in the second quarter of 2019. It is Minesto's ambition to install additional Deep Green devices and gradually expand the Holyhead Deep site to a commercial demonstration array of up to 10 MW installed capacity. In the long-term, the plan is to expand the site to a commercial tidal stream energy array with a total installed capacity of up to 80 MW for which Minesto has submitted a scoping report to UK consenting authorities Marine Management Organisation (MMO) and NRW (i.e. >1 MW project).

Tidal Energy Ltd installed a single 0.4 MW DeltaStream unit off the coast of Pembrokeshire at Ramsey Sound in December 2015. However, in March 2016, an intermittent fault with the sonar system used to detect marine mammals (and thus potential collisions) resulted in the unit being shut down indefinitely as the turbine could not operate within its licence conditions. Later that year, Tidal Energy Ltd went into administration due to market forces. The company had planned to use lessons learned from the Ramsey Sound pilot study to support a larger commercial scale development at St David's Head (10 MW), although this is now unlikely to be progressed.

Nova Innovation, a technology company that designs, builds and operates tidal energy devices, deployed the world's first fully-operational, grid-connected offshore tidal stream energy array at Bluemull Sound in Shetland. The first Nova M100 turbine (0.1 MW) was deployed at the site in March 2016, with second and third turbines added to the array in August 2016 and early 2017. The Crown Estate has awarded Nova Innovation (having teamed up with regional renewable energy organisation YnNi Llŷn) an Agreement for Lease (AfL) to develop a tidal stream energy project at Bardsey Sound (Swnt Enlli) off the Llyn Peninsula in northwest Wales, known as the Enlli Tidal Energy project. The AfL is the first stage in the process that will allow development activity and consenting to formally start on the project; the full Lease will be awarded only once all of the required consents have been secured. The Enlli Tidal Energy project proposes a tidal array with a capacity of up to 2 MW from up to 20 turbines, rated at 100 KW each. The turbines are horizontal axes turbines, with a gravity-based foundation. Each turbine will be connected to an offshore electrical hub that will convert the energy to an exportable format. An offshore subsea cable will transport the energy to the landfall location. A scoping opinion for the proposed development was issued by NRW in November 2018.

The SeaGen tidal stream energy generator (1.2 MW), developed by Marine Current Turbines, was installed in Strangford Lough, Northern Ireland in May 2008. Sea Generation (Wales) Ltd investigated options to install up to five SeaGen units between the Skerries and Anglesey. However, Siemens sold the company and technology to Atlantis Resources in 2015, which in turn reviewed ongoing projects and decided to return the lease area back to The Crown Estate. It is therefore considered unlikely that the Skerries tidal stream energy project will be pursued in the immediate future.

Transition Bro Gwaun (TBG) is a community organisation based in Fishguard, Pembrokeshire. TBG proposes the first community owned/led tidal stream energy project in Wales. The proposed tidal energy project would consist of a small array of Tidal Energy Converters (TECs) deployed off the north Pembrokeshire coast, near Fishguard. TBG seek to deploy up to 10 MW of TECs, while mitigating risk by splitting the development into three stages. The proposed TBG Tidal Energy Development will be located approximately 1.0 km offshore of Strumble Head, near Fishguard, Pembrokeshire. The provisional area of turbine deployment is approximately 2.5 km^2 and has been selected based on peak tidal flows in the region. TBG received a screening and scoping opinion from NRW (August 2018) with NRW confirming that an EIA is required.

Work is underway at the Port of Milford Haven to increase opportunities to support emerging renewables sectors, particularly marine renewables, as part of the Pembroke Dock Marine development. The location offers proximity to natural energy resources, a highly-skilled supply chain and extensive supporting infrastructure. The Marine Energy Engineering Centre of Excellence (MEECE) provides a research and training facility offering practical onsite test and learning opportunities, while the Marine Energy Test Area (META) facilities will provide the consented areas of Milford Haven Waterway close to an operational base with enabling infrastructure to support demonstration projects. In November 2018, Marine Energy Wales submitted an environmental scoping report to the relevant stakeholders for the development of the Marine Energy Test Area (META) project in and around the Milford Haven Waterway.

2.1.2 Wave energy

Definition

Ocean wave energy technologies rely on the up-and-down motion of waves to generate electricity. Energy output is determined by wave height, wave speed, wavelength and water density.

Overview of existing activity

The draft WNMP acknowledges wave technologies are less well developed compared to tidal stream and may take longer to be deployed commercially (i.e. smaller scale test devices offering proof of concept followed by larger-scale arrays). An extensive wave resource exists in both Welsh inshore and offshore waters, particularly in the southwest of Wales which is exposed to waves generated in the Atlantic Ocean. The theoretically extractable annual mean UK wave power resource has been estimated as 43 ± 4 GW, with long-term annual mean wave power levels along the western UK coastline ranging from 25 to 75 kW/m (kilowatts of power potential per metre of wave crest). The UK Atlas of Marine Renewable Energy Resources estimates the theoretical annual mean wave power density to be 15 to 20 kW/m close to the Pembrokeshire coastline, with areas further offshore approaching 30 kW/m (Roche *et al*. 2016 and references therein).

The Pembrokeshire Demonstration Zone, comprising a 90 km^2 area of seabed located between 15 and 21 km from shore with water depths of approximately 50 m, has been leased from The Crown Estate by Wave Hub Ltd (who manage the site in collaboration with partners including Marine Energy Pembrokeshire, Pembroke Port and Pembrokeshire County Council). In February 2018, Wave Hub Ltd submitted a scoping report to the MMO and NRW to develop the site with a mix of wave energy and floating wind technology, providing a maximum total electricity generation of 100 MW.

A feasibility study will be completed in June 2018, which has been part-funded by the Welsh Government and the Welsh European Funding Office. The second phase of work will focus on developing the detailed design and securing consent. It is envisaged that consent for this wave and floating wind demonstration zone could be achieved by 2022 with infrastructure built by 2024.

As described in Section 2.1.1, Pembroke Dock Marine at the Port of Milford Haven is being developed to support emerging renewables energy technology, including potential wave energy projects.

2.1.3 Aquaculture

Definition

In the draft WNMP, aquaculture is described as the rearing or cultivation of aquatic organisms (finfish, shellfish and algae, including support feeds). The activity includes producing livestock for direct commercial purposes (e.g. seafood for human or animal consumption, pharmaceuticals, or algae for fertiliser or energy) or for restocking and enhancing wild populations "ocean ranching".

For the purposes of this study, aquaculture relates to the cultivation of marine organisms in the open sea, an enclosed section of the sea, or in land-based tanks, ponds or raceways filled with seawater. The cultivation of freshwater organisms is excluded.

Overview of existing activity

Commercial aquaculture in Wales has traditionally focused on the managed cultivation of shellfish, principally blue mussels (*Mytilus edulis*). The highest volume of mussel production occurs in the Menai Strait via bottom culture, whilst a lower volume of rope grown mussels are produced in Swansea. Small quantities of Pacific oysters (*Magallana gigas*) are also produced in Wales and a project has been established in Swansea Bay to enhance and manage native oysters (*Ostrea edulis*) with the aim of re-establishing a fishery. The production volume and estimated value of shellfish species cultivated in Welsh waters in 2015 are shown in Table 1. A detailed breakdown of shellfish tonnage and value is not currently available from 2016 onwards; however, it is known that total shellfish production in Welsh waters approximately halved in 2016, compared to 2015[1].

The Shellfish Centre is a research and innovation initiative supporting development of the shellfish sector in Wales. The Centre will collaborate with businesses to deliver science to support growth. The main focus of the project is shellfish aquaculture and the related supply chain, with scope also for research to support new/underexploited shellfisheries and aquaculture of non-shellfish species that are compatible with shellfish production. A workshop organised by the Centre in December 2018 was the first in a series of workshops. This focus of the first workshop was identification of opportunities and constraints for growth for the shellfish production sector in Wales. Relevant outcomes of this initial workshop have been acknowledged within the final report.

[1] Data provided by Cefas, August 2018.

There is currently no sea-based finfish aquaculture production in Wales. Until relatively recently seabass was farmed in land-based recirculation aquaculture systems; however, these facilities are currently being repurposed to farm wrasse as cleaner fish to the Scottish salmon farming industry[2].

Whilst there is currently no commercial scale sea-based production of macroalgae in Wales, offshore cultivation of macroalgae is being piloted in the Eastern Irish Sea by an Industry/Bangor University partnership and research into macroalgae hatchery technology is undertaken at the Centre for Sustainable Aquatic Research (CSAR) at Swansea University. Microalgae (in land-based seawater recirculation systems) are cultivated for both research and commercial purposes (Welsh Government, 2015).

Table 1. Production volumes (tonnes) and imputed value of Welsh shellfish aquaculture in 2015

Species and Production Method	Volume (tonnes)	Estimated Price (£/tonne)	Imputed Value in 2015 (£)
Mussels – off bottom	105	1,496	157,054
Mussels – on bottom	7,012	1,496	10,488,199
Pacific oyster – on bottom	12	2,000	24,000
Total shellfish production	**7,129**		**10,669,253**

Source: Data provided by Cefas, 17.03.17

2.2 Consenting process

Given the similarities in consenting processes for tidal stream energy and wave energy projects, these two focus activities have been combined within Section 2.2.1. However, the consenting process and relevant licensing authorities for aquaculture projects are considered sufficiently distinct from marine renewable energy developments to be discussed separately. The overarching, high-level process for achieving consents for such schemes is described, focusing on marine elements but also highlighting linkages to the terrestrial system where applicable. Decision makers and regulators will be required to determine whether proposed activities comply with the policies outlined in the WNMP, along with other environmental legislation.

2.2.1 Tidal stream energy and wave energy

The NRW Marine Licensing Team considers all applications for activities in the Welsh inshore area. The Welsh inshore area extends seawards 12 nautical miles from Mean High Water Spring (MHWS) to the territorial limit, as defined by the MCAA. This includes any construction works that involve the placement or removal of material in the sea, and thus likely to be relevant to marine renewables projects (e.g. siting of devices/anchoring on the seabed, placement or burial of interconnectors, dredging works during seabed preparation). The NRW Marine Licensing Team must have regard for the need to protect the environment, protect human health and prevent interference with legitimate uses of the sea (as well as other relevant matters). In addition, the requirements of Environmental Impact Assessment (EIA) Directive (2014/52/EU, as amended) must be taken into account, along with other relevant legislation as required.

The EIA Directive (2014/52/EU, as amended) sets out a procedure that must be followed for certain types of project before they can be given consent. The Marine Works (EIA) Amendment Regulations 2017 incorporate the EIA Directive into UK law, identifying projects which require an EIA to be carried out in support of an application for consent as listed in Schedules A1 and A2. All projects listed in

2 https://www.dailypost.co.uk/business/business-news/worlds-largest-salmon-firm-saved-13707760

Schedule A1 are considered to have significant effects on the environment and will therefore always require an EIA. Projects listed within Schedule A2 will only require an EIA if the appropriate authority concludes that the project in question is likely to have significant effects on the environment due to factors such as its size, nature or location. Where unsure, applicants may submit a screening request to the appropriate authority to obtain formal advice on whether an EIA is required.

Offshore renewable energy projects are likely to fall within Schedule A2 and require an EIA where any part of the development is likely to have significant effects on the environment. In Wales, the competent authority for projects with an energy generating capacity up to 1 MW is NRW, for projects between 1 and 100 MW the competent authorities are NRW and MMO and for projects above 100 MW (i.e. Nationally Significant Infrastructure Projects (NSIPs)) is the Secretary of State under the Planning Act 2008. It should be noted that provisions under the Wales Act 2017 indicate that energy generation projects up to 350 MW (excluding wind energy) in Welsh waters are to be consented by Welsh Ministers, with those above 350 MW to be consented by the Secretary of State. However, not all provisions of the Wales Act 2017 are currently in force and thus the NSIP threshold of 100 MW generating capacity currently remains applicable. However, upcoming changes due to the Wales Act mean that on 1 April 2019, the Welsh Ministers will receive devolved powers for on and off shore generating stations up to 350 MW. Should a project promoter wish to apply for consent on a project of between 1 MW and 350 MW on or after this date, the Welsh Ministers will be responsible for deciding the application under Section 36 of the Electricity Act 1989.

The scoping stage of an EIA is an important process that is undertaken to identify the potential environmental issues associated with a proposed development and to determine the scope of work required for the subsequent stages of the EIA process. This includes the identification of any project specific survey requirements, the collation of relevant studies and/or data, the proposed approach to consultation and an agreement of impact pathways and receptors which are to be included, or excluded, from the EIA. Where an Environmental Statement is required to document the EIA process, the Marine Works (EIA) (Amendment) Regulations 2017 set out the minimum information to be included, such as description of the location, physical characteristics of the activity, project alternatives and likely significant effects of the project on the environment. In August 2017, NRW published Guidance Note 13 (GN13) relating to scoping an EIA for marine developments (NRW, 2017).

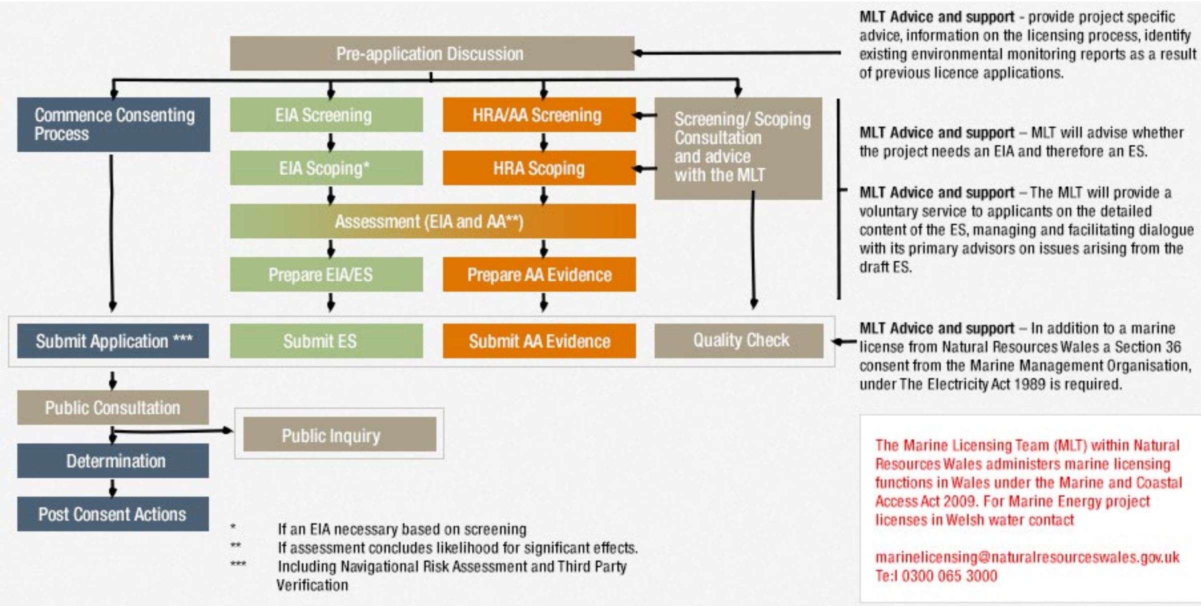
The Habitats Directive (92/43/EEC), Birds Directive (2009/147/EC) and Water Framework Directive (WFD) (2000/60/EEC) play a key role in protecting the environment and have a significant influence on the marine licensing process. Where required, the EIA is supported by specific assessments to determine compliance with the provisions of this legislation. Under the Conservation of Habitats and Species Regulations 2017 (the Habitats Regulations), a competent authority, before deciding to undertake, or give any consent, permission of other authorisation for, a plan or project which:

(a) is likely to have a significant effect on a European site or a European offshore marine site (either alone or in-combination with other plans or projects); and
(b) is not directly connected with or necessary to the management of that site,

must make an appropriate assessment (AA) of the implications of the plan or project for that site in view of that site's conservation objectives. This means that there are specific requirements for assessment of a marine activity or development project that is located close to or within a Special Area of Conservation (SAC), Special Protection Area (SPA) or Ramsar site, or where their designated mobile features have the potential to be affected, wherever they are located. The process for considering development proposals likely to affect these designated sites is known as Habitats Regulations Assessment (HRA) which takes account of the conservation objectives of the site(s) concerned. The HRA process is carried out by the competent authority; however, the information to be used in the HRA should be provided by the applicant.

The WFD establishes a framework for the management and protection of Europe's water resources. The overall objective of the WFD is to achieve "good ecological and good chemical status" in all inland and coastal waters. The initial deadline to meet this objective was 2015; however, in cases where it was not possible to do so due to disproportionate expense, natural conditions or technical feasibility, the deadline to achieve "good ecological and good chemical status" has been extended. In the absence of formal guidance in Wales, the Environment Agency's "Clearing the Waters for All" is considered the most relevant guidance available to consider compliance with WFD objectives. It is understood that internal Operational Guidance Note (OGN) for WFD compliance assessments has been developed by NRW (OGN72). Once published as an external guidance, this should be referenced as opposed to "Clearing the Waters for All".

Tidal stream energy and wave energy projects will largely follow the typical consenting process for any development in the marine environment, as described in guidance provided by Marine Energy Wales (see Image 1). However, wider supporting elements may also be required including, amongst other factors, agreement for the connection of energy generation devices to the grid and the availability and suitability of local port infrastructure to support various stages of the development (e.g. demonstration, fabrication, construction and maintenance). It should be noted that there can be other types of consent required depending on the specifics of a project. For example, a lease agreement with the seabed owner, in most cases The Crown Estate, will be required to install a device on the seabed. Also, once a marine licence has been awarded, licence conditions may stipulate a range of post-consent monitoring to demonstrate the resulting scale of effects of the device and support wider understanding of the sector.



Source: http://www.marineenergywales.co.uk/developers/consenting-guidance

Image 1. Flow chart from Marine Energy Wales for key elements of the marine licence application process in Welsh waters

2.2.2 Aquaculture

The administrative process for the establishment of an aquaculture farm in Wales depends on the nature of the farm (i.e. the species to be farmed and method of cultivation). As such, specific consents and licences required before an aquaculture farm can operate, are location and development dependent. A summary of consents and licences required for aquaculture is provided in Table 2.

Table 2. Required consents for aquaculture developments in Wales

Regulator/Authority	Consent/Authorisation	Applicable Developments		
		Finfish	Shellfish	Seaweed
The Crown Estate (or other landowner where not The Crown)	Foreshore/seabed rights up to 12 nm (for fixed gear aquaculture e.g. raft or buoy cultivation; not usually required for shellfish bottom culture unless access required)	Yes	Yes	Yes
NRW Marine Licensing Team	Marine Licence: ▪ For deposition of equipment on the seabed (where not exempt) (fixed gear aquaculture) ▪ Regarding Navigational Risk (in relation to the presence of infrastructure)*	Yes	Yes (where exemptions do not apply) OR Exemption Notification**	Yes
NRW	Regulations Discharge Consent***	Yes	N/A	N/A
NRW	Abstraction Consent (for land-based premises)	Yes	Yes	Yes
Fish Health Inspectorate	Authorisation for an Aquaculture Production Business (APB)	Yes	Yes	N/A
Welsh Ministers	Several Order (granted under the Sea Fisheries (Shellfish) Act 1967 (for on-bottom cultivation of shellfish out to 6 nm)	N/A	Yes	N/A
Welsh Government	Licence to collect mussel seed (mussel farming only)	N/A	Yes	N/A
Local Authority	Planning Permission (for any onshore facilities e.g. where packaging or processing is undertaken)	Yes	Yes	Yes

* If the proposed development is within a Statutory Harbour Authority (SHA) area the consenting authority will be the SHA;
** Shellfish developments may be issued a Marine Licence Exemption Notification (under the Marine Licensing (Exempted Activities) (Wales) Order 2011) provided the aquaculture structure does not obstruct or cause danger to navigation or is an artificial reef;
*** Discharges from a boat (i.e. a wellboat) would require a Marine Licence (finfish farming only).

Source: Welsh Government (2015); Defra (2015); Information provided by the Welsh Government, 24/01/18

2.3 Key issues

Following stakeholder input during the Cardiff workshop (April, 2018) and further consultations and meetings a number of key issues associated with the focus activities in Welsh waters were highlighted. These issues are related to the following stages of a development:

- **Site selection** – identification of suitable locations in the marine environment which could sustainably accommodate the development due to the prevailing conditions, accessibility and compatibility with other sectors;
- **Feasibility** – consideration of technical capability to deliver the objectives of the development (i.e. aquaculture harvest and renewable energy generation) while acknowledging the economic investment required;
- **Assessment** – understanding the potential effects of the proposed development on the marine environment, specifically through relevant impact pathways, and how this should be assessed and presented;
- **Consenting** – how the consenting process is conducted, reviewed and consulted on, ensuring reasonable timescales to avoid uncertainty and loss of confidence, as well as incorporating various other permissions as required; and
- **Post-consent** – validation of assessments and informing future development while remaining proportionate to the scale of effects anticipated at each individual project level.

In addition, such information will also assist with planning and policy development more generally. Further consideration is given to these issues and how to support sustainable development in Section 5.

Specific issues associated with the individual activities are discussed in the following Sections 2.3.1 to 2.3.3. However, acknowledging comments from stakeholders, at a more general level the lack of readily available evidence and data to support a wider understanding of these activities is, at present, considered a key constraint.

There are difficulties associated with encouraging developers to share data due to commercial sensitivities, while issues can also exist regarding academic ownership of data. A range of data is already accessible on a variety of different portals; however, many of these sources have licensing restrictions for commercial use. Furthermore, data available is not always supported by metadata, limiting the value of readily transferrable and easily disseminated information. Nevertheless, improved signposting to potentially useful sources of data is seen as a benefit to all stakeholders and should be encouraged on data portals where possible.

A better understanding of data required by developers, regulators and statutory stakeholders is needed to reduce uncertainty. For example, all parties need to be confident that the data collection proposed, either by survey or desk study, is fit for purpose i.e. it provides a sound evidence base, while not being unnecessarily time consuming or costly through the provision of data which is either not required or already readily available. Ultimately, there needs to be confidence that the data will address concerns voiced by regulators and stakeholders and therefore not result in delays to the consenting process.

Environmental concerns are a common area for legal challenge and accordingly make regulators and advisors cautious in scoping out issues or in accepting rationalised environmental baselines or assessments. Adoption of the precautionary principle can result in consenting issues where evidence on impact pathways is limited, such as emerging technologies (e.g. tidal stream and wave energy) or activities still developing in Welsh waters, such as aquaculture.

It is important to note that the principles and approaches associated with the draft WNMP general policy 'using sound science responsibly', such as the application of the precautionary principle, taking a risk-based approach and adaptive management, are constrained by law. For example, the Birds and Habitats Directives, associated case law and implementation guidance establish strict procedures for considering the potentially significant effects of plans or projects affecting European protected features. As the majority of Welsh inshore waters are designated as European sites and European protected features occur widely within Welsh waters, the policies and procedures relating to the Birds and Habitats Directives are particularly important considerations for the determination of most marine developments. Case law, such as the Waddenzee judgement, has shown there is a tendency to set high standards for evidence to support development applications.

The strong protection requirements for European sites and features and the high evidence requirements for assessment of potential impacts to these sites/features tends to mean that such issues become the primary focus of decision-making in the marine environment. This is exacerbated by the lack of any significant drivers to consider economic and social factors in project level decision-making (Productive Seas Evidence Group, 2015), although Section 69 of the MCAA does not preclude such consideration. Nevertheless, it is considered that there are opportunities to make better use of risk-based approaches to management, including greater use of adaptive management within decision-making, particularly when considering short-term demonstration projects, for which effects are reversible.

2.3.1 Tidal stream energy

There is a wide range of environmental, consenting and risk issues regarding tidal stream energy developments, as summarised in Table 3. These have been collated from existing marine licence applications (i.e. those in the public domain), including Minesto Phase 1 at Holyhead Deep (Environmental Statement) and the DeltaStream Demonstrator Project at Ramsey Sound (non-technical statement), as well as previous reviews of issues and research priorities (the Marine Renewable Energy Strategic Framework project, 2011; The Crown Estate, 2014; Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy, 2017) and stakeholder input during the workshop in Cardiff (April, 2018).

The summary table (Table 3) indicates how this project has addressed the various issues specifically in relation to identification and collation of relevant data to tidal stream energy. Where data were obtained then a quality assurance process was applied, including an assessment of confidence. Detail on the data gathering and quality assurance methodology is provided in Section 3.

In most cases, unless the issue is explicitly outwith the project scope, then signposting has been used to indicate data that is relevant and available.

Table 3. Key issues associated with tidal stream energy development

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Site Selection	Resource	Tidal resources are predictable, but tidal flows can also present challenging conditions to operate and maintain devices in the marine environment. Determining the optimum location for tidal stream devices, both demonstration and commercial scale arrays, in relation to the resource is a priority for developers (Roche *et al*. 2016). Proposed developments currently appear to be concentrated in high tidal energy locations with high flow rates with the exception of Holyhead Deep (Neill *et al*. 2016), and are thus constrained by the natural resource.	Signposting to existing datasets, including description of data format, accessibility and resolution. Progressed through review of existing datasets and creation of geodatabase.
	Supporting infrastructure	Sufficient infrastructure and capacity to connect developments to the grid could place a restriction on the location of tidal stream developments. The site selection also requires consideration of wider supporting infrastructure, such as links to ports, as well as local content (supply chains are key to these project types).	Issue not within scope of this project.
	Phase diversity	Developers are largely interested in high tidal energy sites; however, it has been suggested that there is minimal phase diversity among these sites and, if all were to be developed in parallel, the aggregated electricity supplied to the grid would be characterised by strong semidiurnal intermittency (at UK scale; Neill *et al*. 2016).	Issue not within scope of this project.
Feasibility	Technical	Emerging technology, such as tidal stream energy, requires innovation and engineers need to work with scientists to create sustainable solutions – there is more uncertainty surrounding novel techniques. A more strategic approach and support for demonstration scale projects would be beneficial, as individual developers would not need to take on all the risks/costs of data collection and assessment. In particular, small-scale projects need more support.	Progressed through review of existing datasets, creation of geodatabase and signposting stakeholders to existing portals sharing information and lessons learned from demonstration scale projects in the UK and other countries.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		It is also important to make use of lessons learnt from elsewhere, such as the European Marine Energy Centre (EMEC) in Scotland and MeyGen tidal projects (now part of Atlantis Resources Ltd). The current focus for tidal stream developers is largely around high tidal flow locations, but research suggests that opportunities for technological developments in tidal stream energy resource could be much higher if deeper water and lower flow sites were developed (Roche *et al*. 2016).	
	Economic	Funding is a key issue for new and emerging technologies. Tidal stream as an industry remains in its infancy and, as such, significant investment is required to conceptualise, develop, test and demonstrate the feasibility of devices before commercial scale arrays can be successfully installed. Confidence in the industry can also drive investment decisions.	Issue not within scope of this project.
Assessment	General (approach)	There is a large range of tidal energy devices, and thus there is a need for a large envelope of assessment. A better understanding of the assessment framework that projects will be considered under is required to provide a consistent and transparent approach. This would need buy-in from all key stakeholders from the outset, including developers, regulators and advisors. Pre-consented areas are a possible way forward, used to assess the full range of possible devices and impacts. Assessment guidance would be useful, as this would provide confidence in methodologies which will be accepted by regulators. For example, the guidance could include types of models (validated and calibrated) that should be used by the developer to assess physical processes issues. This could identify what is required, such as site characterisation, EIA and HRA, and which features/impact pathways are relevant to a particular proposal.	Progressed through signposting of existing guidance for tidal stream developments in relation to impact assessment and consenting. Recommendations for more structured guidance specific to (renewable) developments in Welsh waters. For example, as developed for offshore renewables in Scotland.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		Guidance regarding cumulative effects would also be beneficial (extent, condition and other threats to features), although this is also a wider gap for sectors in the marine environment. However, a risk-based approach should be used which is proportionate to the scale of effects anticipated at the project level (e.g. a single tidal stream device compared to an array of multiple devices). The precautionary principle is a limiting factor and there is a need to better understand how to address and communicate uncertainty. Undefined timescales to complete assessments and make decisions add uncertainty for developers, which in turn can influence investor confidence. It may be possible to use a 'deploy and monitor' approach to boost development of this sector, as applied in Scotland, although this would be challenging to implement in practice. Policies supporting renewable energy technologies such as tidal stream energy need to filter down to the project level.	
	Physical processes	Changes to the surrounding tidal (current/flow) regime as a result of tidal stream energy devices is a key impact pathway associated with this focus activity, with potential modification to the local and wider hydrodynamics and sediment transport regime. Development of hydrodynamic models is required to predict the effects of changes in water flow and energy removal caused by (a) the physical presence of the device in the water and (b) the removal of energy and secondary effects of changes in water flow and energy removal. Coastal sediment transport could be altered by the operation of devices, with localised seabed scouring also a potential impact.	Progressed through signposting existing data and key research outputs relating to the potential impacts of tidal stream energy developments on physical processes.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Water quality	Increased vessel movements during construction and maintenance of devices could present an increased risk of pollution from accidental events. Drilling fluids could enter the marine environment during piling installation.	Although the specific effect of renewables on water quality was not within scope of the current project, data has been collated and signposted on water quality parameters.
	Benthic ecology	As with all installations of infrastructure in the marine environment, there will be a loss of habitat under footprint of the device, whether directly from the siting of the device on the seabed or anchoring. Changes in seabed character could also occur as a result of changes in flow patterns during operation. There is also the potential for the introduction of invasive non-native species (although more likely facilitating their spread) through the provision of a new habitat type (hard structure).	Progressed through the collation and signposting of key scientific evidence relating to impacts of infrastructure installation; however, an extensive scientific evidence review is beyond the scope of the current study. Signposting developers to existing best practice on preventing the spread/introduction of non-native species, for example, the Marine Biosecurity Planning good practice guidance for England and Wales developed by Cook *et al.* (2015).
	Marine mammals	Collision risk and underwater noise are key issues associated with marine mammals. The nature of any potential interactions between marine mammals and tidal stream turbines is uncertain, as well as possible physical consequences of potential collision events. Further development of suitable instrumentation and methodologies for reducing collision risk, monitoring wildlife behaviour around devices and arrays and for detection of any collision events is required. There is a lack of available acoustic data from operational devices and arrays and knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is limited. Increased disturbance from the installation and removal of devices by marine vessel movements could occur, while also presenting a barrier to movement due to the operation of devices/arrays.	Progressed through the collation and signposting of available evidence relating to impacts of tidal stream energy and underwater noise on marine mammals, for example key reviews and/or any lessons learned from monitoring outputs of demonstration/pilot projects in Wales, other parts of the UK or other countries. However, an extensive scientific evidence review was beyond the scope of the current study. Baseline data on the distribution of marine mammals, was collated and signposted through a review of existing datasets.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		The installation of devices could also result in the loss of, disturbance to or displacement from habitats, while also displacing food sources.	
	Birds	The nature of any potential interactions between diving birds and tidal stream turbines is uncertain, as well as possible physical consequences of potential collision events. Further strategic baseline data (distribution, abundance, seasonality, etc.) for birds is required to better understand use of potential development areas. There is potential for disturbance during construction from the presence of installation vessels, loss of underwater foraging habitat (due to installation of devices) and changes to the abundance and distribution of prey, as well as potential for disturbance during operation/maintenance.	Progressed through the collation and signposting of available evidence relating to impacts of tidal stream energy on diving birds, for example key reviews and/or any lessons learned from monitoring outputs of demonstration/pilot projects in Wales, other parts of the UK or other countries. However, an extensive scientific evidence review is beyond the scope of the current study.
	Fish	The nature of any potential interactions between migratory fish and tidal stream turbines is uncertain, as well as possible physical consequences of potential collision events. Further strategic baseline data (distribution, abundance, seasonality, etc.) for migratory fish is required to better understand use of potential development areas. Further data and information regarding the possible effects of electromagnetic fields (EMF) from transmission cables on fish would improve confidence in EIA and HRA. There is a lack of standardised approach to assessing the availability of alternative fishing grounds (outside development areas) and their ability to sustain existing/ displaced commercial fishing levels. Installation of tidal stream devices could result in the loss of spawning/nursery grounds.	Progressed through the collation and signposting of available evidence relating to impacts of tidal stream energy on fish and possible effects of EMF. For example, key reviews and/or any lessons learned from monitoring outputs of demonstration/pilot projects in Wales, other parts of the UK or other countries. However, an extensive scientific evidence review is beyond the scope of the current study.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Cumulative impacts	Need to understand cumulative pressures in proposed development locations and have a strategic approach to ensure Marine Plan is robust and sector development is sustainable.	Progressed through review of existing datasets and creation of geodatabase. Signposting to current condition assessments of protected features and any sources of information about existing pressures in proposed development locations, where information available.
Consenting	Marine licence	Methods/processes are required to help manage perceived and identified environmental risks that may arise from tidal stream energy developments to ensure that project level requirements are proportionate. Agreement is required on the approach to applying a risk based and proportionate approach to consenting tidal arrays (including the design envelope), while methods/processes are also required to predict and measure potential cumulative impacts around clusters of lease areas. Guidance is also needed on wider consenting issues regarding landfall (marine/terrestrial interface) and connection to grid.	Progressed through the collation and signposting of information/evidence relating to impacts of tidal stream energy devices (e.g. from demonstration/pilot studies or research and development). Consideration given to the potential for the co-location of activities and possible cumulative/in-combination effects. Signposting of existing guidance on the consents and permits required for tidal stream energy deployment in Wales. Based on the availability of such guidance recommendations have been made on the requirements for further guidance. However, providing guidance is outside the remit of this project.
	Other permissions	Additional guidance required regarding other permissions and what is required from the developer, such as lease agreements for the installation of devices on the seabed (e.g. The Crown Estate).	Progressed through collation and signposting to existing guidance on the consents and permits required for tidal stream energy deployment in Wales. Based on the availability of such guidance recommendations have been made on the requirements for further guidance. However, providing guidance is outside the remit of this project.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Decommissioning	Further guidance is required as to how best to consider decommissioning in the consenting process.	Progressed through collation and signposting existing guidance on the consents and permits required for tidal stream energy deployment in Wales. Based on the availability of such guidance recommendations have been made on the requirements for further guidance However, providing guidance is outside the remit of this project.
Post-consent	Monitoring requirements	Agreement is required between developers and regulators on the approach to developing Project Environmental Monitoring Plans and incorporating adaptive management strategies, for commercial scale arrays. Monitoring data should be captured in a way that informs future consenting (e.g. Shetland video footage) to help build on lessons learnt. Post-consent monitoring should also be used to highlight/acknowledge any positive impacts on developments and highlight where issues were not encountered to inform future assessment requirements.	Encouraging an iterative process. Communicating examples of Environmental Monitoring Plans, adaptive management strategies and lessons learned from these processes as they become available.

2.3.2 Wave energy

Development of the wave energy industry is at an earlier stage than tidal stream energy. However, there are a wide range of identified environmental, consenting and risk issues regarding wave energy developments, as summarised in Table 4. These have been collated from existing marine licence applications (i.e. those in the public domain), including the Wave Hub environmental statement (Halcrow, 2006), as well as previous reviews of issues and research priorities (the Marine Renewable Energy Strategic Framework project, 2011; The Crown Estate, 2014; ORJIP Ocean Energy, 2017) and stakeholder input during the workshop in Cardiff (April, 2018).

The summary table (Table 4) indicates how this project has addressed the various issues specifically in relation to identification and collation of relevant data to wave energy. Where data were obtained then a quality assurance process was applied, including an assessment of confidence. Detail on the data gathering and quality assurance methodology is provided in Section 3.

In most cases, unless the issue is explicitly outwith the project scope, then signposting has been used to indicate data that is relevant and available.

Table 4. Key issues associated with wave energy development

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Site Selection	Resource	Wave resources are less predictable than tidal stream. Good resources generally occur in areas that experience large fetch, such as the draft SRA for wave energy which is situated off the coast of southwest Wales and thus exposed to waves generated from the Atlantic Ocean. Locations for feasible wave energy resource can present challenging conditions to operate and maintain devices in the marine environment. Determination of the optimum location for devices in relation to the resource is a priority for developers (Roche *et al*. 2016).	Signposting to existing datasets, including description of data format, accessibility and resolution. Progressed through review of existing datasets and creation of geodatabase.
	Supporting infrastructure	Sufficient infrastructure and capacity to connect developments to the grid could place a restriction on the locality of wave energy developments. The site selection also requires consideration of wider supporting infrastructure, such as links to ports, as well as local content (supply chains are key to these project types).	Issue not within scope of this project.
Feasibility	Technical	The current atlas for estimating wave energy resource requires further investigation and updating. Wave buoys are relatively inexpensive and could support greater understanding, although there are additional data processing costs that need to be acknowledged. There are three sites currently undergoing feasibility studies for the deployment of wave energy converter technology in Wales, all off the south Pembrokeshire coast, and in relatively close proximity to Milford Haven port (Roche *et al*. 2016).	Progressed through review of existing datasets, creation of geodatabase and signposting to existing portals sharing information and lessons learned from demonstration scale projects in the UK and other countries.
	Economic	Funding is a key issue for new and emerging technologies. Wave energy generation as an industry remains in its infancy (more so compared to tidal stream energy) and, as such, significant investment is required to conceptualise, develop,	Issue not within scope of the current project.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		test and demonstrate the feasibility of devices before commercial scale arrays can be successfully installed. Confidence in the industry can also drive investment decisions.	
Assessment	Physical processes	Changes to the surrounding wave regime is a key impact pathway associated with this focus activity, with the potential to alter coastal processes. Development of hydrodynamic and wave models is required to predict the effects of changes in water flow and energy removal caused by (a) the physical presence of the device in the water and (b) the removal of energy and secondary effects of changes in water flow and energy removal.	Progressed through signposting to existing data and key research outputs relating to the potential impacts of wave energy developments on physical processes.
	Water quality	Increased vessel movements during construction and maintenance of devices could present an increased risk of pollution from accidental events. Drilling fluids could enter the marine environment during installation of tethering structures.	Although the specific effect of renewables on water quality is not within scope of the current project, data has been collated and signposted on water quality parameters.
	Benthic ecology	As with all installations of infrastructure in the marine environment, there will be a loss/disturbance of habitat under footprint of the device, including anchoring. Changes in seabed character could also occur as a result of changes in flow patterns during operation. There is also the potential for the introduction of invasive non-native species (although more likely facilitating their spread) through the provision of a new habitat type (hard structure).	Progressed through the collation and signposting of key scientific evidence relating to impacts of infrastructure installation; however, an extensive scientific evidence review is beyond the scope of the current study. Signposting developers to existing best practice on preventing the spread/introduction of non-native species, for example, the Marine Biosecurity Planning good practice guidance for England and Wales developed by Cook *et al.* (2015).
	Marine mammals	The nature of any potential interactions between marine mammals and wave energy devices is uncertain, as well as possible physical consequences of potential collision events. However, there is less risk to marine mammals from wave	Progressed through the collation and signposting of available evidence relating to impacts of wave energy and underwater noise on marine mammals, for example key reviews

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		energy than from tidal stream. Further development of suitable instrumentation and methodologies for reducing collision risk and monitoring wildlife behaviour around devices and arrays is required. There is a lack of available acoustic data from operational devices and arrays and knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is limited. Increased disturbance from the installation and removal of devices by marine vessel movements could occur, while also presenting a barrier to movement due to the operation of devices/arrays. The installation of devices could also result in the loss of, disturbance to or displacement from habitats, while also displacing food sources. Further strategic baseline data (distribution, abundance, seasonality, etc.) for marine mammals is required to better understand use of potential development areas.	and/or any lessons learned from monitoring outputs of demonstration/pilot projects in Wales, other parts of the UK or other countries. However, an extensive scientific evidence review is beyond the scope of the current study. Baseline data on the distribution of marine mammals, collated and signposted through a review of existing datasets.
	Birds	Further strategic baseline data (distribution, abundance, seasonality, etc.) for birds is required to better understand use of potential development areas. There is potential for disturbance to offshore and intertidal birds during construction from the presence of installation vessels, loss of underwater foraging habitat (due to installation of devices) and changes to the abundance and distribution of prey. The effects on designated features could vary during specific times of year (e.g. overwintering bird populations).	Progressed through the collation and signposting of existing datasets; however, this was generally limited to distribution data. Signposting of available evidence relating to bird disturbance, for example key reviews (although an extensive scientific evidence review is beyond the scope of the study).
	Fish	The nature of any potential interactions between migratory fish and wave energy devices is uncertain, as well as possible physical consequences of potential collision events. However, there is less risk to fish from wave energy than from tidal	Collation and signposting of available evidence relating to impacts of wave energy on fish and possible effects of EMF, for example key reviews and/or any lessons learned from monitoring

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		stream. Further strategic baseline data (distribution, abundance, seasonality, etc.) for migratory fish is required to better understand use of potential development areas. Further data and information regarding the possible effects of EMF from transmission cables on fish would improve confidence in EIA and HRA. There is a lack of standardised approach to assessing the availability of alternative fishing grounds (outside development areas) and their ability to sustain existing/ displaced commercial fishing levels. Installation of wave energy devices could result in the loss of spawning/nursery grounds.	outputs of demonstration/pilot projects in Wales, other parts of the UK or other countries. However, an extensive scientific evidence review was beyond the scope of the current study.
	Cumulative impacts	Need to understand cumulative pressures in proposed development locations and have a strategic approach to ensure Marine Plan is robust and sector development is sustainable.	Progressed through review of existing datasets and creation of geodatabase. Signposting to current condition assessments of protected features and any sources of information about existing pressures in proposed development locations.
Consenting	Marine licence	Methods/processes are required to help manage perceived and identified environmental risks that may arise from wave energy developments to ensure that project level requirements are proportionate. Agreement is required on the approach to applying a design envelope approach to consenting wave energy arrays, while methods/processes are also required to predict and measure potential cumulative impacts around clusters of lease areas. Guidance is also needed on wider consenting issues regarding landfall (marine/terrestrial interface) and connection to grid.	Progressed through the collation and signposting of information/evidence relating to impacts of wave energy devices (e.g. from demonstration/ pilot studies or research and development). Consideration has been given to the potential for the co-location of activities and possible cumulative/in-combination effects. Signposting of existing guidance on the consents and permits required for wave energy deployment in Wales. Based on the availability of such guidance recommendations have been made on the requirements for further guidance.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
			However, providing guidance is outside of the remit of this project.
	Other permissions	Additional guidance required regarding other permissions and what is required from the developer, such as lease agreements for the installation of devices (e.g. The Crown Estate).	Progressed through collation and signposting to existing guidance on the consents and permits required for wave energy deployment in Wales. Based on the availability of such guidance recommendations have been made on the requirements for further guidance. However, providing guidance is outside of the remit of this project.
	Decommissioning	Further guidance is required as to how best to consider decommissioning in the consenting process.	Progressed through collation and signposting to existing guidance on the consents and permits required for tidal stream energy deployment in Wales. Based on the availability of such guidance, recommendations have been made on the requirements for further guidance. However, providing guidance is outside the remit of this project.
Post-consent	Monitoring requirements	Agreement is required between developers and regulators on the approach to developing Project Environmental Monitoring Plans and incorporating adaptive management strategies, for commercial scale arrays. Monitoring data should be captured in a way that informs future consenting (e.g. Wave Energy Scotland) to help build on lessons learnt. Post-consent monitoring should also be used to highlight/acknowledge any positive impacts on developments and highlight where issues were not encountered to inform future assessment requirements.	Encouraging an iterative process. Communicating examples of Environmental Monitoring Plans, adaptive management strategies and lessons learned from these processes as they become available.

2.3.3 Aquaculture

The potential environmental impacts of aquaculture will depend on the type of aquaculture (i.e. finfish, shellfish or seaweed). There are a wide range of potential environmental, consenting and risk issues particularly for sea-based finfish, and to a lesser extent shellfish and seaweed farming, as summarised in Table 5, Table 6 and Table 7 respectively. These have been collated from specific issues raised at the stakeholder workshop in Cardiff (April, 2018) and through consultation and meetings with stakeholders as well as wider experience of aquaculture development in the UK and elsewhere.

The summary table (Table 5) indicates how this project has addressed the various issues specifically in relation to identification and collation of relevant data to the different types of aquaculture. Where data were obtained then a quality assurance process was applied, including an assessment of confidence. Detail on the data gathering and quality assurance methodology is provided in Section 3.

In most cases, unless the issue is explicitly outwith the project scope, then signposting has been used to indicate data that is relevant and available.

Table 5. Key issues associated with aquaculture of marine finfish species

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Site selection	Resource	Developers need information relating to physical parameters to aid site selection (wave height, tidal streams, water depth, temperature, salinity etc.). Although existing datasets may be available, the resolution may not be sufficient for site level assessments.	Progressed through a review of existing datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, quality assurance (QA) status, data format, accessibility (e.g. available to download as spatial data layers) and resolution.
	Water quality	Information on water quality parameters, and potential for harmful algal blooms (HABs).	Progressed through a review of existing datasets, research outputs and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers). Signposting recent and ongoing research initiatives in the UK (e.g. ShellEye project).
	Competition for space	Knowledge of other marine sector distribution and intensity is an important consideration in site selection. However, there is limited existing data for some sectors, and where data are available on the Wales Marine Planning Portal, stakeholders highlighted that some data were not fit for purpose (e.g. inshore fisheries data).	Progressed through a review of existing datasets and creation of a geodatabase.
Feasibility	Technical	Due to the relatively exposed nature of the Welsh coastline (e.g. compared to Scottish sea lochs) the feasibility of different cultivation technologies in more offshore locations (especially for finfish farming which is not currently undertaken in Welsh waters) is uncertain.	A review of the feasibility of different technologies was outside the scope of the current project. Site conditions required to support this activity were considered as part of the site selection/resource review (see above).

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Supporting infrastructure and supply chain	Sufficient infrastructure and access to the wider supply chain (processing units and markets) may place a restriction on the locality of aquaculture developments (e.g. larger distances to essential supporting services have a cost implication for developments).	Issue not within the scope of the current project, although signposting to relevant ongoing projects (e.g. Aqua coast, Milford Haven) has been included.
Assessment	General	Access to existing ecological baseline data (e.g. on biological receptors), resolution of data and ability to assess the quality/ confidence in data (e.g. prior to purchasing).	Progressed through review of existing datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers).
	General	There are a range of potential impacts from aquaculture which, in general, are likely to be of greater concern to regulators in inshore areas. It was suggested that a detailed evidence-base relating to the potential impact of aquaculture, based on the existing scientific literature, would be beneficial to both developers and regulators.	Collation and signposting of available evidence relating to impacts of aquaculture, for example key reviews such as the 'Review of the environmental impacts of salmon farming in Scotland' (Scottish Association for Marine Science (SAMS), 2018). However, an extensive scientific evidence review was beyond the scope of this report.
	Water/sediment quality	Organic waste accumulation on the seabed (through deposition of faeces and uneaten food), eutrophication of waterbodies (through release of dissolved nutrients), any subsequent changes in plankton communities and chemical contamination (from veterinary treatments and anti-foulants) are key impact pathways of concern for finfish farming.	There is currently no sea-based finfish farming in Wales. However, there is interest in establishing this sector and addressing the key impact pathways of concern through technology (e.g. inshore closed loop systems; siting farms further offshore where impacts may be reduced) although the feasibility of such technology in Welsh waters is currently not known. Progressed through signposting to key scientific reviews of the impacts of fish farming (e.g. SAMS, 2018), noting that impacts are site and development specific.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Benthic ecology	Smothering (through the deposition of faeces and uneaten food) and any subsequent impacts on benthic communities (arising from organic enrichment/deoxygenation) are considered key impact pathways for finfish developments.	There is currently no sea-based finfish farming in Wales. However, there is interest in establishing this sector and addressing the key impact pathways of concern through technology (e.g. inshore closed loop systems; siting farms further offshore where impacts may be reduced) although the feasibility of such technology in Welsh waters is currently not known. Progressed through signposting to key scientific reviews of the impacts of fish farming (e.g. SAMS)2018) (noting that impacts are site and development specific). Impacts relating to suspended mussel culture have been well studied in the scientific literature. Signposting to general lessons learned from suspended mussel farming in the UK and other countries and to key scientific reviews.
	Fish	The potential transfer of pathogens and/or parasites between cultured stock and wild populations, and the potential for genetic interaction between escaped farm fish and wild populations, are key impact pathways for fish farming. Data relating to the migratory routes of wild populations would help to inform impact assessments. Other sustainability issues relate to impacts on wild fish resources, arising from harvesting for aquaculture feed (fishmeal and fish oil) and biological parasite control (i.e. harvesting of wild wrasse for use as cleaner fish in the Scottish salmon industry).	Detailed data on salmonid migratory routes is not a focus for this project (not technically feasible as wild populations too low). Progressed through signposting to any existing datasets that may help inform assessments. General sustainability issues, relating to harvesting of wild fish species for feed and parasite control in finfish farming is not within the remit of this project. However, in general, sustainable use of fishmeal and fish oil has improved and research is ongoing into potential alternative ingredients in feed.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
			Furthermore, an initiative is underway in Wales to develop a land-based hatchery facility for the sustainable production of cleaner fish (wrasse) for use in Scottish salmon farms.
	Birds	Management of predators (e.g. anti-predator netting to stop seabirds predating on fish) may be an issue depending on farm location and the population and distribution of bird species of concern. Data on the latter would help inform assessments and site selection.	Progressed through the collation and signposting of existing datasets; however, this was generally limited to distribution data.
	Marine mammals	Management of predators (seals with respect to finfish farming) would be a key issue for any finfish farms in Wales. Data on seal haul outs and colonies would help inform assessments and site selection.	Progressed through a review of existing datasets and creation of geodatabase; however, this was generally limited to distribution data.
	Cumulative impacts	Need to understand cumulative pressures in proposed development locations and have a strategic approach to ensure Marine Plan is robust and sector development (including meeting 2020 production targets stated in draft WNMP) is sustainable.	Progressed through a review of existing datasets and creation of geodatabase. Consideration given to the potential for the co-location of activities, Integrated Multi-Trophic Aquaculture (IMTA) and possible cumulative/in-combination effects. Signposting to current condition assessments of protected features and sources of information about existing pressures in these locations.
Post-consent	Monitoring requirements	Any post-consent monitoring data requirements should be captured in a way that informs future consenting to help build on lessons learnt. Post-consent monitoring should also be used to highlight/acknowledge any positive impacts on developments and highlight where issues were not encountered to inform future assessment requirements.	Encouraging an iterative process. Communicating examples of Environmental Monitoring Plans, adaptive management strategies and lessons learned from these processes as they become available.

Table 6. Key issues associated with aquaculture of marine shellfish species

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Site selection	Resource	Developers need information relating to physical parameters to aid site selection (wave height, tidal streams, water depth, temperature, salinity etc.). Although existing datasets may be available, the resolution may not be sufficient for site level assessments.	Progressed through a review of existing datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers) and resolution.
	Water quality	Information on water quality parameters (good water quality is particularly important for shellfish aquaculture), and potential for harmful algal blooms (HABs).	Progressed through a review of existing datasets, research outputs and creation of geodatabase. Signposting to existing datasets, including description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers). Signposting recent and ongoing research initiatives in Wales (e.g. Human Pathogens and Shellfish in the Conwy, Menai Strait and Burry Inlet; Bangor University) and rest of UK (e.g. ShellEye project).
	Competition for space	Knowledge of other marine sector distribution and intensity is an important consideration in site selection. However, there is limited existing data for some sectors, and where data are available on the Wales Marine Planning Portal, stakeholders highlighted that some data were not fit for purpose (e.g. inshore fisheries data).	Progressed through a review of existing datasets and creation of geodatabase. This exercise informed additional data collection requirements.
Feasibility	Technical	Due to the relatively exposed nature of the Welsh coastline, as compared to Scottish sea lochs, the feasibility of different cultivation technologies in more offshore locations is uncertain, although trials for some forms of shellfish/seaweed culture in more exposed/offshore locations have been piloted in Welsh waters (Welsh Government, 2015).	A review of the feasibility of different technologies was outside the scope of this project Site conditions required to support this activity were considered as part of the site selection/resource review (see above).

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
	Supporting infrastructure and supply chain	Sufficient infrastructure and access to the wider supply chain (processing units and markets) may place a restriction on the locality of aquaculture developments (e.g. larger distances to essential supporting services have a cost implication for developments).	Issue not within the scope of the current project.
Assessment	General	Access to existing ecological baseline data (e.g. on biological receptors), resolution of data and ability to assess the quality/ confidence in data (e.g. prior to purchasing).	Progressed through review of existing datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers).
	General	There are a range of potential impacts from aquaculture which, in general, are likely to be of greater concern to regulators in inshore areas. It was suggested that a detailed evidence-base relating to the potential impact of shellfish aquaculture, based on the existing scientific literature, would be beneficial to both developers and regulators.	Collation and signposting of available evidence relating to impacts of shellfish aquaculture, for example key reviews and outputs of industry/science research projects in Wales. However, an extensive scientific evidence review was beyond the scope of this project.
	Water/sediment quality	Organic waste accumulation on the seabed (through deposition of faecal matter). Changes to sediment due to deposition of faeces and shell drop.	Progressed through signposting to key scientific reviews of the impacts of mussel farming (noting that impacts were site and development specific).
	Benthic ecology	A key impact pathway is potential introduction of invasive non-native species (INNS) (e.g. via transfer with shellfish seed) or through the introduction of new non-native species for culture if settlement in the wild occurs. An example of the latter is the Pacific oyster (*Magallana gigas*), which despite having been cultivated in the UK for many decades and being an important economic species for the shellfish sector, is now the focus of tension between continued production and risk to biodiversity	In Wales, there is an established process in place to address biosecurity related to the translocation of seed mussels from other areas. Signposting to information regarding this process and biosecurity guidance.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		due to wild settlement of the species in some areas of the UK (e.g. the west and south east England). Another example of a non-native species farmed in the UK is the manila clam (*Ruditapes philippinarum*), although this species is not currently farmed in Wales. There is potential for the benthic community to be affected by faecal and shell drop from farms. Chronic accumulation of shells may alter the substratum.	
	Birds	Management of predators (e.g. the use of netting to prevent species of duck, such as common scoter, predating on mussels) may be an issue depending on farm location, cultivation method (e.g. rafts, longlines) and the population and distribution of the bird species. Data on the latter would help inform assessments and site selection.	Progressed through the collation and signposting of existing datasets; however, this was generally limited to distribution data.
	Cumulative impacts	Need to understand cumulative pressures in proposed development locations and have a strategic approach to ensure Marine Plan is robust and sector development (including meeting 2020 production targets stated in draft WNMP) is sustainable.	Progressed through a review of existing datasets and creation of geodatabase. Consideration given to the potential for the co-location of activities, Integrated Multi-Trophic Aquaculture (IMTA) and possible cumulative/in-combination effects. Signposting to current condition assessments of protected features and sources of information about existing pressures in these locations.
Consenting	Seed supply	The majority of mussels produced in Wales are cultivated on the seabed in mussel lays and is dependent on the ability to collect and relay wild mussel seed into these areas. Collection of wild mussel seed, which occur in ephemeral beds, requires a permit and the length of time to gain this permit has resulted in this resource no longer being available and hence lost to the industry.	Issue not within the scope of this project.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
		A stakeholder suggestion at the workshop was that there may be the potential to address this issue via assessing the feasibility of a mussel hatchery, as per other areas of the UK. A European study involving Bangor University and a Welsh industry partner (EU CRAFT project No 017729) – looked at the potential development of a reliable supply of high quality seed for blue mussel farming (BLUE SEED). At the time, it was concluded that hatchery production of mussel seed in Europe is only economically feasible where the product has an added value such as triploidy.	
	Fishery Several Orders	The majority of mussel farming in Welsh Waters occurs in Several Order fisheries which grant exclusive fishing or management rights within a designated area and allow legal ownership of certain named shellfish species in a private shellfishery for a defined period of time. The relatively short duration of leases, agreement of Several Order Fishery terms and the time for Several Order Fisheries to be renewed are key issues considered to result in a lack of security which undermine the continued viability of current producers and potentially discourage new entrants to the industry.	Issue not within the scope of this project
Post-consent	Monitoring requirements	Any post-consent monitoring data requirements should be captured in a way that informs future consenting to help build on lessons learnt. Post-consent monitoring should also be used to highlight/acknowledge any positive impacts on developments and highlight where issues were not encountered to inform future assessment requirements.	Encouraging an iterative process. Communicating examples of Environmental Monitoring Plans, adaptive management strategies and lessons learned from these processes as they become available

Table 7. Key issues associated with aquaculture of marine seaweed species

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Site selection	Resource	Developers need information relating to physical parameters to aid site selection (wave height, tidal streams, water depth, temperature, salinity etc.). Although existing datasets may be available, the resolution may not be sufficient for site level assessments.	Progressed through review of available datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers) and resolution.
	Water quality	Information on water quality parameters	Progressed through review of available datasets and creation of geodatabase. Included signposting to existing datasets, description of data collection methodology, QA status, data format, accessibility (e.g. available to download as spatial data layers).
	Competition for space	Knowledge of other marine sector distribution and intensity is an important consideration in site selection. However, there is limited existing data for some sectors, and where data is available on the Wales Marine Planning Portal, stakeholders highlighted that some was not fit for purpose (e.g. inshore fisheries data).	Progressed through review of existing datasets and creation of geodatabase. This exercise informed additional data collection requirements.
Feasibility	Technical	Due to the relatively exposed nature of the Welsh coastline (e.g. compared to Scottish sea lochs) the feasibility of different cultivation technologies in more offshore locations is uncertain, although trials for some forms of seaweed culture in more exposed/offshore locations have been piloted in Welsh waters (Welsh Government, 2015).	A review of the feasibility of different technologies was outside the scope of this project. Site conditions required to support this activity were considered as part of the site selection/resource review (see above).
	Supporting infrastructure and supply chain	Sufficient infrastructure and access to the wider supply chain (processing units and markets) may place a restriction on the locality of aquaculture developments (e.g. larger distances to essential supporting services have a cost implication for developments).	Issue not within the scope of this project.

Project Stage		Key Issues	Stakeholder Requirement and How Project Has Addressed
Assessment	General	There are a range of potential impacts from aquaculture including seaweed culture, which in general, are likely to be of greater concern to regulators in inshore areas. It was suggested that a detailed evidence-base relating to the potential impact of seaweed aquaculture, based on the existing scientific literature, would be beneficial to both developers and regulators.	There is currently no commercial sea-based seaweed farming in Wales, although trials for some forms of shellfish/seaweed culture in more exposed/offshore locations have been piloted in Welsh waters (Welsh Government, 2015). Progressed through collation and signposting to available evidence relating to impacts of seaweed culture in UK. For example, review by Wood *et al.* (2017). However, an extensive scientific evidence review is beyond the scope of this project
	Cumulative impacts	Need to understand cumulative pressures in proposed development locations and have a strategic approach to ensure Marine Plan is robust and sector development (including meeting 2020 production targets stated in draft WNMP) is sustainable.	There is currently no commercial sea-based seaweed farming in Wales, although trials for some forms of shellfish/seaweed culture in more exposed/offshore locations have been piloted in Welsh waters (Welsh Government, 2015). Progressed through review of existing datasets and creation of geodatabase. Consideration will also be given to the potential for the co-location of activities, IMTA and possible cumulative/in-combination effects. Signposting to current condition assessments of protected features and sources of information about existing pressures in these locations.
Post-consent	Monitoring requirements	Any post-consent monitoring data requirements should be captured in a way that informs future consenting to help build on lessons learnt. Post-consent monitoring should also be used to highlight/acknowledge any positive impacts on developments and highlight where issues were not encountered to inform future assessment requirements.	Encouraging an iterative process. Communicating examples of Environmental Monitoring Plans, adaptive management strategies and lessons learned from these processes as they become available

3 Data Collation

3.1 Overall approach

The main objective of this project was to address the need for fit for purpose (synthesised, interpreted, quality assured and refined) spatial data, and knowledge, to support baseline characterisation and sustainable development of tidal (stream) energy, wave energy and aquaculture resources.

The specific aims of the data collation exercise were to identify existing spatial data for key receptors for each of the focus activities and identify existing marine evidence in Welsh waters and apply a standardised quality assurance and confidence assessment to the data available.

Where possible, data were sourced with potential relevance to tidal (stream) energy, wave energy and aquaculture resources, for potential development in Wales and for wider marine spatial planning. Data of wider and generic relevance to the project and marine developments was also collated, interpreted and quality assured, as appropriate.

Data covering all project stages of the three focus activities was collated and/or signposted. This captured, for example, data to inform:

- **Marine planning and site selection** – including specific parameters/requirements associated with each of the three focus activities;
- **Baseline description** – environmental baseline including characterising receptors for which a potential impact pathway exists. Includes the location, extent and condition of features that are recognised within the MPA network in Welsh waters. It also includes the mapped locations of known activities and resulting pressures as well as the distribution and presence of stakeholders that occur/are represented within a particular location. Noting that this information is likely to be useful for contextual purposes and in practice the collection of site specific data is likely to be required for the assessment of individual projects;
- **Assessments and consenting** – these datasets are effectively the same as those identified for the baseline description, where impact assessments will be determined in the context of the detailed baseline environment; and
- **Post-consent** – while these datasets were not available at the outset, recommendations are made as to how they can feed back in to the pool of available evidence and inform future development. Signposting to the potential availability of these datasets has been used where applicable.

The collation of these datasets resulted in the creation of an evidence database (excel workbook, see Appendix I.1) and geodatabase (ESRI ArcGIS, see Appendix I.2) which incorporate data relevant to each of the three focus activities (see Section 1.3).

The process undertaken to collate, analyse and assess the suitability of data to inform site selection and provide contextual baseline information of tidal stream, wave energy and aquaculture developments is presented in Figure 5. Each process is discussed in more detail in Sections 3.2 to 3.6 below.

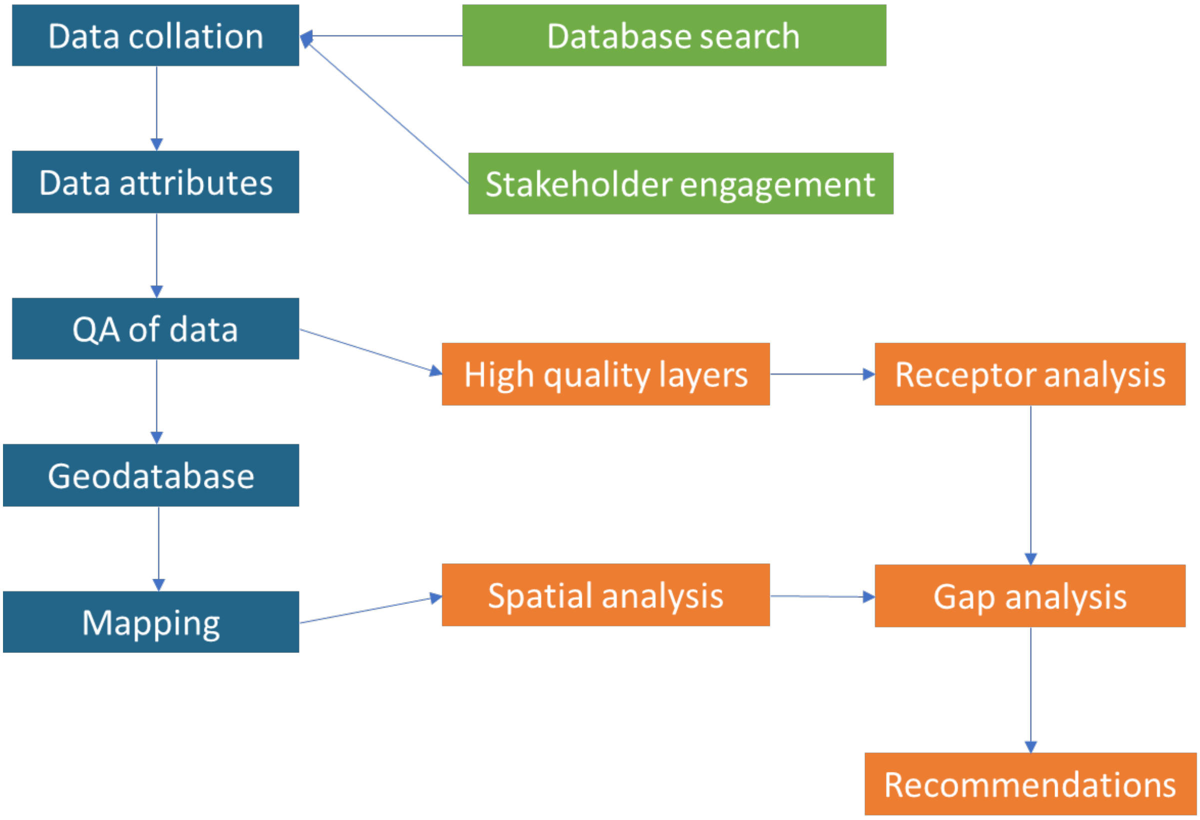


Figure 5. Method used to identify existing spatial data in Welsh waters to inform sustainable development of tidal stream, wave energy and aquaculture resources

Although the principal focus of the data review relates to the draft SRAs, as presently defined, it is recognised that the boundaries of these areas may change, while the policies of the final marine plan may also differ from those set out in the draft WNMP. Furthermore, potential environmental effects arising from these activities may extend beyond the draft boundaries of the SRAs, as currently defined.

As such, the data review covers a broad geographical area, which encompasses all Welsh waters, and thus provides flexibility for the developing marine plan whilst ensuring that the collation and signposting of data considered relevant to developers for these focus activities is not geographically constrained.

Figure 6 provides the wider study area, over which available data sets have been collated.

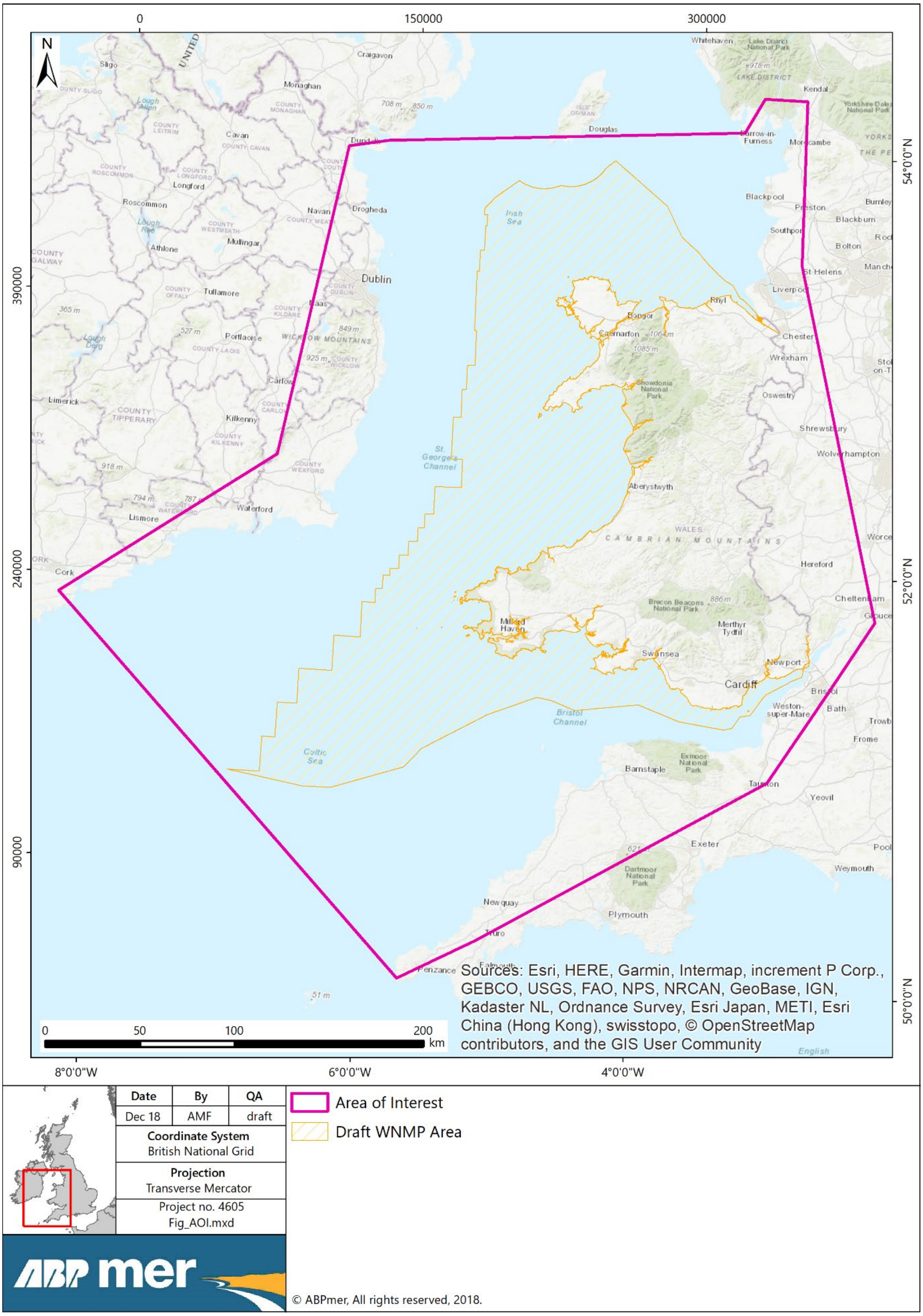


Figure 6. Wider study area

3.1.1 Welsh Marine Planning Portal Review

A standalone report (ABPmer, 2018b) has been produced which reviews the Welsh Marine Planning Portal (WMPP). A key aspect of the review includes the identification of gaps in the portal (in the context of both the data requirements of this project and wider initiatives).

In carrying out the wider exercise of identifying relevant datasets for the focus activities, the WMPP was interrogated, along with other data sources. Hence, the identification of gaps in the WMPP was carried out in tandem with the broader work and is detailed within subsection 3.6.5 below. Similarly, where data recommendations are made in Section 6 of this report, these are also relevant to the WMPP.

3.2 Data collation

A data mining exercise identified a comprehensive list of evidence sources for informing site selection and baseline condition assessments. Initially, datasets that could potentially be used to inform site selection for tidal (stream) energy, wave energy and aquaculture resource development, and that could be used to inform wider MSP within Welsh waters, were identified through an extensive review of the NRW data library (NRW, 2018).

Following the initial search, a wider review of publicly available databases and online mapping facilities was carried out to identify further relevant datasets. Key sources of data were derived from the following:

- Lle Geo-Portal (http://lle.gov.wales/home);
- Wales Marine Planning Portal (http://lle.gov.wales/apps/marineportal);
- NRW Library Catalogue (https://libcat.naturalresources.wales/webview);
- Marine Environmental Data and Information Network (MEDIN) Data Discovery Portal (http://portal.oceannet.org/portal/start.php);
- United Kingdom Directory of Marine Observing Systems (UKDMOS) (http://www.ukdmos.org);
- The Crown Estate's Marine Data Exchange (http://www.marinedataexchange.co.uk);
- Joint Nature Conservation Committee (JNCC) Activities-Pressures Evidence Base (http://jncc.defra.gov.uk/default.aspx?page=7136);
- Marine Ecosystems Research Programme (http://www.marine-ecosystems.org.uk/Home);
- National Biodiversity Network (NBN) Atlas Wales (https://nbn.org.uk/about-us/where-we-are/in-wales/nbn-atlas-wales);
- LIFE Natura 2000 Programme for Wales (https://www.naturalresources.wales/about-us/our-projects/nature-projects/life-n2k-wales/life-n2k-wales/?lang=en);
- Wales Environment Link (http://www.waleslink.org);
- Condition assessment, WFD, Marine Strategy Framework Directive (MSFD; 2008/56/EC) and shellfish water protected area monitoring data;
- Seabird colony register (http://jncc.defra.gov.uk/page-1776);
- Seabirds at Sea database (http://jncc.defra.gov.uk/page-4469);
- British Trust for Ornithology (BTO) Wetland Bird Survey (WeBS) data (https://www.bto.org/volunteer-surveys/webs/data);
- Small Cetaceans in European Atlantic waters and the North Sea (SCANS) reports
- Sea Watch Foundation (http://www.seawatchfoundation.org.uk);
- ORJIP (http://www.orjip.org.uk);

- Wave Energy Scotland Knowledge Library (https://library.waveenergyscotland.co.uk);
- Offshore Renewable Energy (ORE) Catapult (https://ore.catapult.org.uk);
- Data from demonstration zones (http://www.marineenergywales.co.uk/marine-energy-in-wales/demonstration-zones; http://www.morlaisenergy.com; https://www.wavehub.co.uk/pembrokeshire-wave-zone);
- Marine Renewable Energy Strategic Framework (http://gov.wales/topics/environmentcountryside/energy/renewable/marine/framework/?lang=en);
- MEECE (http://www.marineenergywales.co.uk/marine-energy-in-wales/projects/pembroke-dock-marine);
- Integrated Marine Data and Information System (iMarDIS) (https://www.imardis.org);
- Regulation 35 Advice (e.g. https://www.gov.uk/guidance/conservation-advice-for-marine-protected-areas-how-to-use-site-advice-packages);
- Standing Committee on Seals;
- Environment Agency migratory fish data;
- Cefas fish surveys;
- Aquaculture Research Collaborative Hub – UK (ARCH-UK) (https://www.aquaculturehub-uk.com);
- ShellEye Project (http://www.shelleye.org);
- Irish Sea Portal Pilot (http://www.irelandwales.eu/projects/irish-sea-portal-pilot-ispp);
- Bord Iascaigh Mhara (BIM) (http://www.bim.ie);
- Offshore energy and Severn Tidal Power Strategic Environmental Assessments (SEAs);
- Research community (e.g. Proudman Oceanographic Laboratory (POL), Bangor and Swansea);
- Defra MB0102 - MPA data layers;
- Devolved administrations;
- RSPB - Tracking seabirds to inform conservation of the marine environment (FAME STAR tracking studies; and
- EIA baseline, pre-construction and post-consent surveys – private developers.

Additionally, as part of the data collation phase, a range of developers, statutory agencies and other stakeholders were contacted to request any datasets which were not publicly available. A list of organisations contacted along with their response is provided in Appendix C.

A complete list of all the data sources collated for the project is provided in the evidence database, supplementary to this report and submitted as part of this project (see Appendix I.1). The contents of the data were documented, including data types and key attributes/metadata. Where it was not possible to obtain the actual dataset, the potential availability of the data was signposted. Similarly, if known, datasets that are currently being collected or processed that could be useful in the future (particularly at a strategic scale) were identified and signposted. Additionally, in some instances data could not be collated but the resultant maps or accompanying reports could be sourced. Where this occurred, the reports have been highlighted in the literature evidence reference list in Appendix D.

3.3 Data attributes

Data were organised and assessed according to the following receptors:

- Physical;
- Chemical (including water and sediment quality);

- Biological;
  - benthic habitats and species – including those on the OSPAR list and Section 7 lists;
  - fish – including migratory species;
  - mammals – seals, cetaceans and otters;
  - birds – seabirds and wading birds;
- Human environment – e.g. licensing, other infrastructure, conflicting activities; and
- Administrative boundaries – e.g. protected areas.

Data sources were classified as relevant to the focus activities, recognising the clearly different requirements and technologies of each activity, including differences within marine finfish, shellfish and seaweed aquaculture.

There is currently no commercial seaweed cultivation in Wales or marine finfish aquaculture. However, consideration of these types of aquaculture has been included to encompass the possibility of future proposals.

A wide range of different types of environmental data are required to inform site selection/baseline characterisation of areas for each of the three focus activities. In general, there was considerable overlap between the data requirements of the focus activities, hence, many of the data requirements were the same irrespective of the activity (Table 8).

Where a specific data source and, if available, dataset was relevant to more than one focus activity or receptor type it was replicated accordingly within the evidence database and geodatabase.

Once data were collated within the evidence database a number of attributes were captured for each data layer which helped to inform the quality assurance phase of the project (Section 3.4). Attributes captured included; temporal and spatial extent of the data, data type (point, polygon, polyline), organisation data source, point of contact, licence requirements and update frequency. If the data layer was available from multiple sources this was also highlighted where possible.

Table 8. Types of environmental data required for each of the three focus activities during site selection and baseline characterisation stages of a project

	Tidal Energy		Wave Energy		Aquaculture					
					Finfish		Shellfish		Seaweed	
	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline
Physical										
Bathymetry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tides/waves	✓	✓	✓	✓	✓		✓		✓	
Wind		✓		✓	✓		✓		✓	
Substrata	✓		✓		✓		✓	✓	✓	
Sea surface temperature		✓		✓	✓	✓	✓	✓	✓	✓
Salinity		✓		✓	✓		✓	✓	✓	✓
Chemical										
Dissolved oxygen		✓		✓	✓	✓	✓	✓	✓	✓
Heavy metals					✓	✓	✓	✓	✓	✓
Contaminants (not heavy metals)		✓		✓	✓	✓	✓	✓	✓	✓
Nutrients		✓		✓	✓	✓	✓	✓	✓	✓
Biological										
Phytoplankton/zooplankton		✓		✓	✓	✓	✓	✓	✓	✓
Microbial (coliforms)					✓	✓	✓	✓	✓	
Non-native species	✓	✓	✓	✓	✓	✓	✓	✓		✓
Benthic habitats and species										
Distribution		✓		✓	✓	✓	✓	✓	✓	✓
Protected habitat and species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fish										
Distribution		✓		✓		✓				
Nursery habitats	✓		✓		✓					
Spawning habitats	✓		✓		✓		✓			
Migratory species	✓	✓	✓	✓	✓	✓		✓		✓
Mammals										
Distribution: cetaceans	✓	✓	✓	✓	✓					
Distribution: seals	✓	✓	✓	✓	✓					
Distribution: otters	✓	✓	✓	✓	✓					
Collision risk areas	✓	✓	✓	✓						
Noise disturbance		✓		✓		✓		✓		✓

	Tidal Energy		Wave Energy		Aquaculture					
					Finfish		Shellfish		Seaweed	
	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline	Site Selection	Baseline
Birds										
Distribution: seabirds	✓	✓	✓	✓	✓					
Distribution: wading birds					✓	✓	✓	✓		
Risk mapping	✓		✓							
Human environment										
Marine licences	✓		✓		✓		✓		✓	
Energy: coastal power stations	✓		✓		✓		✓		✓	
Energy: electricity interconnectors	✓		✓		✓		✓		✓	
Energy: oil and gas					✓		✓		✓	
Energy: tidal	✓		✓		✓		✓		✓	
Energy: wave	✓		✓		✓		✓		✓	
Energy: wind	✓		✓		✓		✓		✓	
Marine aggregates	✓		✓		✓		✓		✓	
Pipelines and cables	✓		✓		✓		✓		✓	
Ports and shipping	✓		✓		✓		✓		✓	
Tourism and recreation	✓		✓		✓	✓	✓	✓	✓	✓
Fisheries	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aquaculture	✓		✓		✓	✓	✓	✓	✓	✓
Landscape/seascape amenity	✓		✓		✓	✓	✓	✓	✓	✓
Historic environment/cultural heritage	✓		✓		✓		✓		✓	
Bathing waters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Shellfish waters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Defence	✓		✓		✓		✓		✓	
Other marine infrastructure	✓		✓		✓		✓		✓	
Administrative boundaries										
Protected area boundaries (conservation designated sites)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EC Directive reporting units	✓		✓		✓		✓		✓	
Land ownership	✓		✓		✓		✓		✓	

3.4 Quality assurance

The relative quality of each of the collated datasets were evaluated according to a series of set criteria, to determine their appropriateness for use in identifying potentially suitable locations for each of the focus activities, or for use in baseline characterisation through the provision of contextual information (Sections 3.4.1 to 3.4.4). The method used was adapted from the MESH confidence assessment protocol (MESH, 2007) and JNCC Protocol E (JNCC, 2012a) for the purposes of this project

A standardised list of questions and responses were used to evaluate and score each of the datasets according to the various assessment criteria (Table 9). The cumulative score for a given dataset was then calculated and the level of confidence provided (Table 10).

The key criteria that each data set was assessed against includes:

- Appropriateness;
- Methodology;
- Timeliness; and
- Accuracy/ Ground truthing.

Each of these criteria are described in more detail in Sections 3.4.1 to 3.4.4 below.

3.4.1 Appropriateness

Appropriateness was assessed to ensure that the piece of evidence is appropriate for its intended use and can be used to inform the question that has been posed. For example, is the data relevant to national marine spatial planning (including site selection) and/or environmental assessments? Is data sufficient to inform baseline characterisation? Is the resolution sufficient for what the data is representing? Does it overlap spatially with the marine plan area?

Appropriateness →

Questions to ask
1 – Is the spatial extent appropriate for intended purpose?
2 – Is data provided in an appropriate format?
3 – Is data appropriate to inform either site selection or baseline / assessment stages?

3.4.2 Methodology

This assessed the method used to collect or produce the data layer or evidence. It assesses if there is a clear explanation of the data collection methodology used and was it robust enough.

Methodology →

Questions to ask
1 – Is there clear explanation of the methodology provided with the dataset?
2 – Is the methodology considered best practice for the type of data?
3 – Is the dataset based on modelled or collected information?

3.4.3 Timeliness

Age of the evidence is an important consideration. Depending on the nature of the evidence, out of date evidence has the potential to affect the user confidence. This criterion assessed what period of time the data represents, how old the dataset is, and how much of an effect this could have on its accuracy today.

For example, biological datasets may become out of date within several years; however, geological datasets will have a much longer lifespan. For this assessment, a shorter timeframe is applied to marine habitats that show high temporal variation and for highly mobile species or activities/pressures that change location.

Within this criterion, acknowledgment is also given to the six-yearly reporting cycle outlined in the Marine and Coastal Access Act (2009).

Temporal Extent →

Questions to ask
1 – When was the dataset created?
2 – What time period does the dataset have coverage for?
3 – What impact does this have on the dataset's relevance today?

3.4.4 Accuracy/Ground-truthing

Accuracy/ground-truthing aims to ensure that any evidence used has been collected, processed and published with rigour and that appropriate quality assurance processes are in place. For example, has any ground-truthing taken place, and for evidence that relies on modelled data has an unbiased statistical accuracy assessment been provided? Also, how has data been processed, has a quality assessment process been put in place, and have the collectors considered accuracy of data?

Accuracy →

Questions to ask
1 – Has ground truthing been undertaken?
2 – Is there clear explanation of the ground truthing method used?
3 – If the data has been modelled, has a statistical assessment been completed to evaluate the accuracy of the data?

3.4.5 Overarching scoring

Considering each of the criteria described above an overarching scoring system was developed to assess each data layer. The scoring was a collation of all of the above criteria, which measured the wider considerations of data use, such as data coverage for use in MSP, data which have been compiled from multiple data sets, and judgment as to its use in informing site selection of the focus activities and the provision of contextual baseline information. Where data have been collated from multiple datasets, for example the NRW 'Marine Article 17 reporting habitat features' and 'Marine Regulation 35 Feature Maps' original data sources needed to be clearly stated with a defined methodology to achieve a high score. Scoring additionally, considered the overall quality and applicability of the collated layer to inform site selection and baseline characterisation of the focus activities.

The full assessment is shown in Table 9. Following assessment of each criteria an overall score was provided for each data set (Table 10). This score was used to define high scoring data layers that could potentially be useful to inform site selection and/ or for baseline characterisation for each of the three focus activities (Section 3.6.2).

Table 9. Quality assurance scoring based upon defined assessment criteria

Purpose	Score Requirements		
	High (3)	Medium (2)	Low (1)
Appropriateness			
Marine planning/ Site Selection	▪ Data covers a large proportion of the MSP area (>50%) ▪ Data collected at national (Wales) or international level and covers a large proportion of the adjoining MSP area ▪ Data is high resolution ▪ Data provides mapped information on location, extent and condition of mapped feature/activity/pressure ▪ Feature/activity/pressure considered directly relevant for spatial planning ▪ Data have been collected specifically for spatial planning purposes	▪ Data covers a large proportion of the MSP area ▪ Data collected at national level and provides useful data on baseline condition ▪ Data is low resolution ▪ Data identifies presence of feature/activity/pressure ▪ Feature/activity/pressure considered relevant for spatial planning ▪ Data have been collected as part of standard monitoring e.g. SAC condition monitoring.	▪ Data is local and covers only a small proportion of the MSP area – could be useful for local planning ▪ Data is low resolution ▪ Data only provides an indication of presence/absence of feature/activity/pressure ▪ Feature/activity/pressure considered indirectly relevant for spatial planning ▪ Data not collected to specifically assess current status of species/habitat/ feature
Baseline/ Assessment	▪ Data covers a large proportion of one or more relevant SRAs ▪ Data is high resolution ▪ Data appropriate for site selection/scheme assessment – direct spatial overlap Data provides mapped information on location, extent and condition of mapped feature/activity/pressure	▪ Data covers a large proportion of the MSP area, but limited coverage in SRA areas. ▪ Data is broadscale ▪ Data identifies presence of feature/activity/pressure	▪ Data is local and covers only a small proportion of the MSP area, not direct spatial overlap with SRA areas. ▪ Data is broadscale ▪ No direct spatial overlap ▪ Data only provides an indication of presence/absence of feature/activity/pressure

Purpose	Score Requirements		
	High (3)	Medium (2)	Low (1)
Methodology			
Site Selection	▪ Data collected using a defined, best practice methodology ▪ Data is polygon data, no further interpretation needed ▪ Data has a built-in confidence assessment ▪ Data collected from direct observation	▪ Data collected using a defined, best practice methodology ▪ Data point or polyline interpretation needed ▪ Data has a built-in confidence assessment ▪ Data collected from direct observation	▪ Data collected using a method not considered best practice ▪ Data point or polyline interpretation needed ▪ Based only on modelled data ▪ No confidence assessment ▪ Data collected via questionnaire or third-party observations
Baseline/ Assessment	▪ Data collected using a defined, best practice methodology ▪ Data has a built-in confidence assessment	▪ Data collected using a defined, best practice methodology ▪ Data point or polyline interpretation needed ▪ Data has a built-in confidence assessment	▪ Data collected using a method not considered best practice ▪ Based only on modelled data ▪ No confidence assessment
Timeliness (age of data)			
Species	▪ < 6 years – Benthic species ▪ < 3 years - Highly mobile or ephemeral species	▪ 6 – 12 years - Benthic species ▪ 3 – 9 years - Highly mobile or ephemeral species	▪ > 12 years – Benthic species ▪ > 9 years - Highly mobile or ephemeral species
Biogenic habitat	▪ < 6 years	▪ 6 – 12 years	▪ > 12 years
Geogenic habitat	▪ < 6 years	▪ 6 – 18 years	▪ > 18 years
Geology	▪ < 6 years	▪ 6 – 18 years	▪ > 18 years
Chemical/ physical/activity	▪ < 6 years	▪ 6 – 18 years	▪ > 18 years

Purpose	Score Requirements		
	High (3)	Medium (2)	Low (1)
Accuracy/Ground truthing			
Marine Planning/ Site selection	▪ The dataset is provided with excellent details on quality assurance methods to recognised QMS practices ▪ The data sources are clearly stated for modelled datasets ▪ Dataset has been expertly reviewed ▪ Presence of feature supported by interpreted ground truthing data (e.g. video, still image, grab, diver survey). ▪ Quantifiable or verifiable evidence to demonstrate presence of feature ▪ Habitat extent supported by survey data (habitat map survey or remote sensing data)	▪ The dataset is provided with some details on quality assurance methods ▪ The data sources are clearly stated for modelled and collated datasets ▪ Dataset has been expertly reviewed ▪ Habitat extent supported by survey data (habitat map survey or remote sensing data) for some of the area ▪ Quantifiable or verifiable evidence to demonstrate presence of 'parent' feature within EUNIS classification hierarchy (e.g. EUNIS Level 2 Circalittoral rock, rather than EUNIS Level 3 High Energy Circalittoral rock	▪ Dataset does not provide adequate detail on QA method ▪ The data sources are not clearly stated for modelled or collated datasets ▪ No evidence of ground truthing for data ▪ Ground truthing based solely on expert judgement and/or the evidence has not been reviewed
Baseline/ Assessment	▪ Ground truthing undertaken. E.g. underwater video surveys, additional mapping/ interpolation of data ▪ Habitat extent supported by survey data (habitat map survey or remote sensing data) ▪ Multiple records confirming habitat presence (80% overlap in data) ▪ The data sources for collated datasets have been clearly stated	▪ Ground truthing based solely on expert judgement ▪ Modelled data has a statistical assessment ▪ Evidence to demonstrate presence of 'parent' feature within EUNIS classification hierarchy (e.g. EUNIS Level 2 Circalittoral rock, rather than EUNIS Level 3 High Energy Circalittoral rock) ▪ Multiple records confirming habitat presence (50% overlap in data)	▪ No evidence of ground truthing for data ▪ Few records confirming habitat presence ▪ The data sources are not clearly stated for modelled or collated datasets

Table 10. Overall assessment ratings (cumulative scores from QA assessment tables)

Rating	Confidence	Definition	Potential considerations
0	Unable to assess	Metadata could not be sourced.	▪ Incomplete or no metadata. Quality and confidence could not be assessed
1-5	Low	Insufficient detail is available to assess confidence in the evidence. Low confidence in the evidence. Decision makers must be aware that there are limitations to use in MSP, and developer's aware of limitation to assessment. Further investigation will be required.	▪ The techniques and methods used may not be the accepted, best practice method. ▪ Incomplete or no metadata. ▪ No clarity if the data are measured, modelled, predicted or estimated. ▪ Data extent is limited and not relevant for national planning. ▪ No clarity when recorded, over what period. ▪ No quality control procedures identified at the point of evidence collection or during processing. No published quality control or quality management system (QMS) in place at originating organisation.
5 - 8	Moderate	Good quality evidence but may lack internal quality assurance, full documentation of methods, and/or have inaccuracies.	▪ Methodology published but unable to determine if followed best current practice of a professional standard. ▪ Data are modelled, predicted or estimated with details of such procedures provided. ▪ Data covers a large proportion of Welsh waters. ▪ Data are measured but precision is low or unclear. ▪ Uncertainty regarding age of data. ▪ Detailed metadata and sufficiently well populated to allow some evaluation. ▪ Some quality control information published at the point of evidence collection and/or during processing. A published quality control process and/or QMS is evident at the originating organisation.
9 - 12	High	High quality evidence, internally quality assessed, high confidence in methodology. Suitable for use in MSP.	▪ Detailed methodology published and using known best practice of a professional standard. ▪ Data are measured, and precision is high and explicitly stated. ▪ Data extent are directly relevant for MSP ▪ Full date and update information is provided. ▪ Detailed quality control procedures or ground truthing methods published at the point of evidence collection and/or during processing. A published quality control process and/or QMS are evident at the originating organisation, in the case of a QMS this is accredited to a known standard (such as ISO9001).

3.5 Geodatabase

Following the data mining and collation exercise (as described above), any data sets obtained were stored into an ESRI ArcGIS format geodatabase. Initially this geodatabase included all data collated within the evidence database (Appendix I.1), irrespective of quality, coverage, relevance etc., providing a 'Master' dataset. Subsequent data processing was then carried out to refine the collated data, based on the objectives and aims of the present study. The processing steps are described further in the following Sections.

3.5.1 Data type

The vast majority of the sourced data sets were obtained in GIS feature class or ascii grid format. There were a few instances where tabulated data was collected and, where this contained spatial information (i.e. coordinates for data locations), these have been mapped and a geospatial data layer created.

Overall, the datasets collected fall into one of the following four data types:

- ESRI Point shapefile feature class – point location data;
- ESRI Polyline shapefile feature class – geospatial line data;
- ESRI Polygon shapefile feature class – geospatial area data; and
- ESRI Grid data – regularly gridded data defining a surface, containing cell attributes.

The data type of each layer is evident from within the ESRI geodatabase and is also logged within the accompanying Excel-format evidence database.

3.5.2 Data processing

Once spatial data layers were collated, they were processed to enable their subsequent use in the wider study.

Projection and datums

Data layers were defined using a range of spatial reference frames, including World Geodetic System (WGS), Universal Transverse Mercator (UTM) and Ordnance Survey of Great Britain (OSGB). In order to maintain a consistent approach to the definition and storage of the collated data layers, all features were re-projected into WGS84 format.

The WGS84 projection was already applied within the majority of the collated data layers and was therefore the most efficient choice of coordinate system to re-project those that weren't.

No processing was carried out in relation to vertical reference datums. As a result, any data layers containing elevation data (e.g. bathymetry, topography data) maintain the vertical datum of the original dataset.

Spatial coverage

With a consistent set of data layers, the next step in processing was to ensure the data included features within the defined Area of Interest (AoI) for this study, this formed a buffer around Welsh waters (as defined in Figure 6). Using the ESRI ArcGIS software package, the complete set of data layers were analysed and the individual features which intersected the Area of Interest were identified.

Any data that fell outside of the AoI were clipped out of their respective data layer, resulting in a dataset containing only information relevant to the defined AoI.

For the majority of the collated data layers, this stage resulted in a set of features clipped to the AoI. However, in a few cases, all of the features within the original data layer were identified as being outside of the AoI and hence, once clipped, resulted in an empty data layer. Where this occurred, the resultant empty file was removed from the clipped geodatabase, and the accompanying entry removed from the evidence database. In this way, only data relevant to Welsh waters (the AoI) was included within the geodatabase.

3.5.3 Final geodatabase structure and content

Once collation and subsequent processing was completed, the resultant geodatabase contained:

- A complete set of data layers projected onto a consistent horizontal reference frame;
- Only data relevant to the defined Area of Interest;
- Data relevant to the specific Sectors of interest (tidal stream and wave energy, aquaculture); and
- A total of 432 individual data layers (comprising a range of point, line, polygon and gridded data types), with an overall file size of around 2.6 Gb.

The final geodatabase product, which accompanies this report, is provided as a specific deliverable from the present study, see Appendix I.2.

Following quality assessment only high scoring layers within the evidence database (see Appendix I.1) and the geodatabase (see Appendix I.2) were included in the mapping process described in Section 3.5.4. This does not mean that the data excluded are not of use for informing tidal stream, wave energy and aquaculture development, but that data may require further interpretation, or that care should be taken before using the data to determine areas for sectoral developments.

A subset of 214 high scoring layers were included in the mapping process. This subset of data forms the focus of assessment for data gaps, and recommendations for future monitoring.

3.5.4 Mapping

All mapping was carried out using ArcGIS 10.4. Data were clipped to the AoI so that only relevant data to Welsh MSP were analysed.

Following collation of data in the geodatabase, mapping of the high scoring data layers was undertaken to assess the spatial coverage of high scoring data and to start to identify data gaps (see Section 3.5.5). This was achieved by creating heat maps to analyse areas of high, or low, data coverage.

Grids of 1 km and 10 km sizes were created. A spatial join was then undertaken between the high scoring layers and the grids to allow mapping. Scoring was then carried out to summarise the number of data points in each grid for each focus activity, and for each receptor, to create the heat maps. This identified areas of high data coverage and indicated spatial gaps in the data collated.

Proposed SRA areas were overlaid on to the maps to help assess data availability within the areas, for informing and justifying SRA selection. Maps produced as part of this stage of the project are presented in Appendix E.

3.5.5 Data gaps

This project aimed to collate and signpost all available evidence with respect to the three focus activities and to, where possible, highlight any data gaps. The identification of data gaps built on the data collation phase and the heat maps produced, as described in Section 3.5.4 above.

Gap analysis was based on consideration of:

- Data layers recommended for the three focus activities, and wider marine planning, taking account of the temporal and spatial resolution of the data where possible;
- Spatial distribution of data within Welsh waters, including within SRA areas (heat mapping).

The main focus of the gap analysis was on broad data requirements (Table 8) to support site selection or baseline characterisation of tidal stream, wave energy or aquaculture developments. The results of this analysis are discussed within the data overview (Section 3.6).

3.6 Data overview

3.6.1 All data

A total of 432 potentially relevant datasets were identified for the three focus activities and for potential use in marine spatial planning. These were reviewed against the pre-defined QA criteria (Table 9) and are provided in the evidence database (see Appendix I.1).

The number of datasets identified for each of the three focus activities against each receptor type during site selection and baseline/assessment phases is summarised in Table 11. The tidal stream and wave energy activities have been amalgamated as these encompassed the same receptor datasets (see Table 8). Additionally, datasets that could potentially inform aquaculture activities for finfish, shellfish and seaweed aquaculture were amalgamated within the database to avoid duplication of data layers, however it is recognised that the different activities will have varying requirements (see Table 8 for more detail).

Table 11. Summary of data layers identified for focus activities against each receptor. Unshaded cells represent recommended data layers for a given activity/phase

	Tidal Stream and Wave Energy		Aquaculture	
	Site Selection	Baseline	Site Selection	Baseline
Physical				
Bathymetry	5	1	1	2
Tides/waves	11	1	9	
Wind	2			
Substrata	8	1	7	3
Sea surface temperature		3	2	3
Salinity				
Chemical				
Dissolved oxygen				
Heavy metals				
Contaminants (not heavy metals)	1	17	16	18
Nutrients		1	1	1

	Tidal Stream and Wave Energy		Aquaculture	
	Site Selection	Baseline	Site Selection	Baseline
Biological				
Phytoplankton/zooplankton		2	1	2
Microbial (coliforms)		1	1	1
Non-native species	4	4	4	4
Benthic habitats and species				
Distribution	27	107	106	109
Protected habitat and species	98	93	97	96
Fish				
Distribution	2	2	1	1
Nursery habitats	1		1	
Spawning habitats	1		1	
Migratory species	9	14	14	14
Mammals				
Distribution: cetaceans	19	13	18	
Distribution: seals	11	8	11	
Distribution: otters	6	6	6	
Collision risk areas				
Noise disturbance		1		
Birds				
Distribution: seabirds	9	9	9	
Distribution: wading birds	1		1	1
Risk mapping	1			
Human environment				
Marine licences	11	11	10	10
Energy: coastal power stations			1	1
Energy: electricity interconnectors	1	1	1	1
Energy: oil and gas	3	3	5	5
Energy: tidal	2	2	2	2
Energy: wave	2	2	2	2
Energy: wind	1	1	1	1
Marine aggregates	10	10	10	10
Pipelines and cables	3	3	3	3
Ports and shipping	7	7	7	7
Tourism and recreation	9	9	11	11
Fisheries	12	12	12	12
Aquaculture			2	2
Landscape/seascape amenity			1	1
Historic environment/cultural heritage	3	3	3	3
Bathing waters	1	1	1	1
Shellfish waters			4	4
Defence	1	1	1	1
Other marine infrastructure	3	3	3	3

	Tidal Stream and Wave Energy		Aquaculture	
	Site Selection	Baseline	Site Selection	Baseline
Administrative boundaries				
Protected area boundaries (conservation designated sites)	15	15	14	15
EC Directive reporting units	1		1	
Land ownership				

3.6.2 High scoring data

Following the collation exercise, datasets were then identified which represented the best scoring data for a particular receptor and/or development stage and for wider MSP.

Data with an overall assessment rating of between 9 and 12 were assessed as high quality with high confidence, were considered important datasets for informing marine spatial planning and baseline characterisation of the focus activities. This resulted in a total of 214 distinct datasets (see High Scoring Layers sheet in Appendix I.1).

Table 12 provides a summary of the available high scoring datasets for the focus activities Figure 7 shows the spatial distribution of high scoring layers. Biological data accounted for approximately 65% of all high scoring data layers.

Table 12. High scoring data layers per sector

	Tidal Stream and Wave Energy		Aquaculture	
	Site Selection	Baseline	Site Selection	Baseline
Physical	14	4	8	3
Chemical	1	7	8	8
Biological	86	137	139	135
Human Environment	37	37	39	39
Administrative Boundaries	13	12	13	12

As a further assessment of high scoring data layers, metadata was assessed to verify if it meets MEDIN data standards. This process verified that the metadata had all relevant metadata fields completed. All mandatory fields needed to be filled correctly to be validated, for example, format; contact; lineage; datum/units etc. If this criterion was not met data were not considered to meet MEDIN standards. All data sourced from statutory agencies including NRW, JNCC and the Environment Agency were assumed to meet the required metadata standards.

As a first step it is recommended that developers, stakeholders and regulators reference the high scoring datasets, as identified through the quality assurance process (3.4), to assist with siting and assessment of the focus activities. The following sections provide a breakdown of the data currently available for the focus activities with an emphasis on high quality data. These data will also provide a useful resource for future marine planning activities within Welsh waters.

In addition to Figure 7, additional maps which display the distribution of key data layers for tidal stream and wave energy, and aquaculture are available in Appendix E. Draft SRAs and designated sites (SSSIs, SACs, SPAs and MCZs) are overlain on these maps.

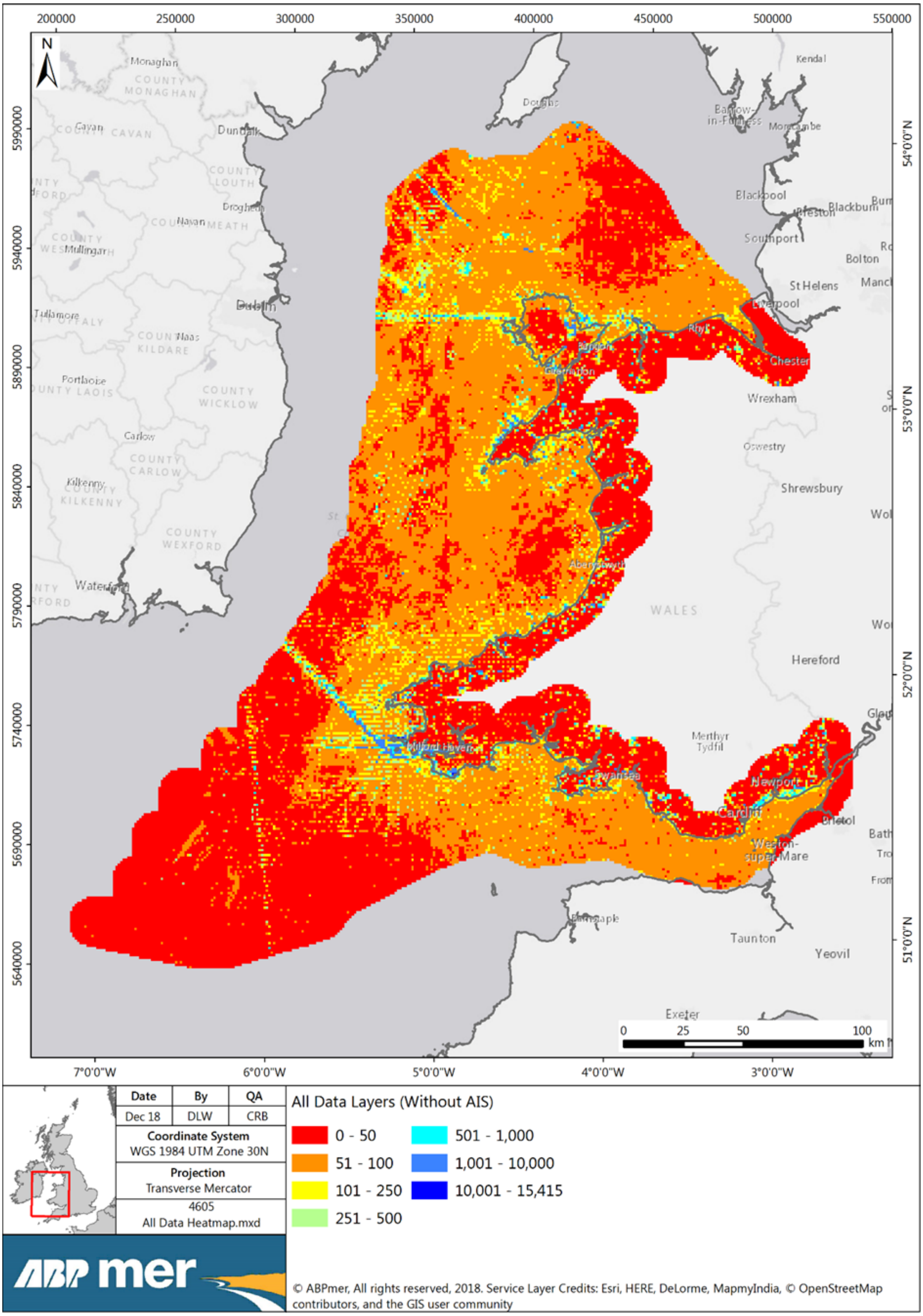


Figure 7. **Heat map of all high scoring data layers within Welsh waters (relative data density per km²)**

3.6.3 Tidal stream and wave energy

As part of the data collation tidal stream and waver energy were assessed together due to the high overlap in data requirements for both focus activities. 300 layers were considered to aid in informing tidal stream and wave energy site selection and 303 for baseline and assessment. However, of those approximately half were considered high scoring layers and as such potentially of greater use for planning and consenting activities (Table 12).

Physical

Physical data including bathymetry, tide and wave data, and substratum are considered important for site selection of tidal stream and wave energy devices. No major gaps were identified for informing site selection of tidal and wave devices and several high scoring layers including the marine renewable atlas and EMODnet provide a useful starting point. Additionally, there was a high-level of spatial coverage for physical data within draft SRAs for both tidal stream and wave energy, at the resolution of informing general planning activities. Distribution of physical data was also relatively even across the whole Welsh marine plan area, however, there is unlikely to be enough data to fully support siting and assessment of the focus activities. Additionally, the south west had less coverage than the rest of Welsh waters, and as such there is less data available for the wave energy draft SRA (Figure 8).

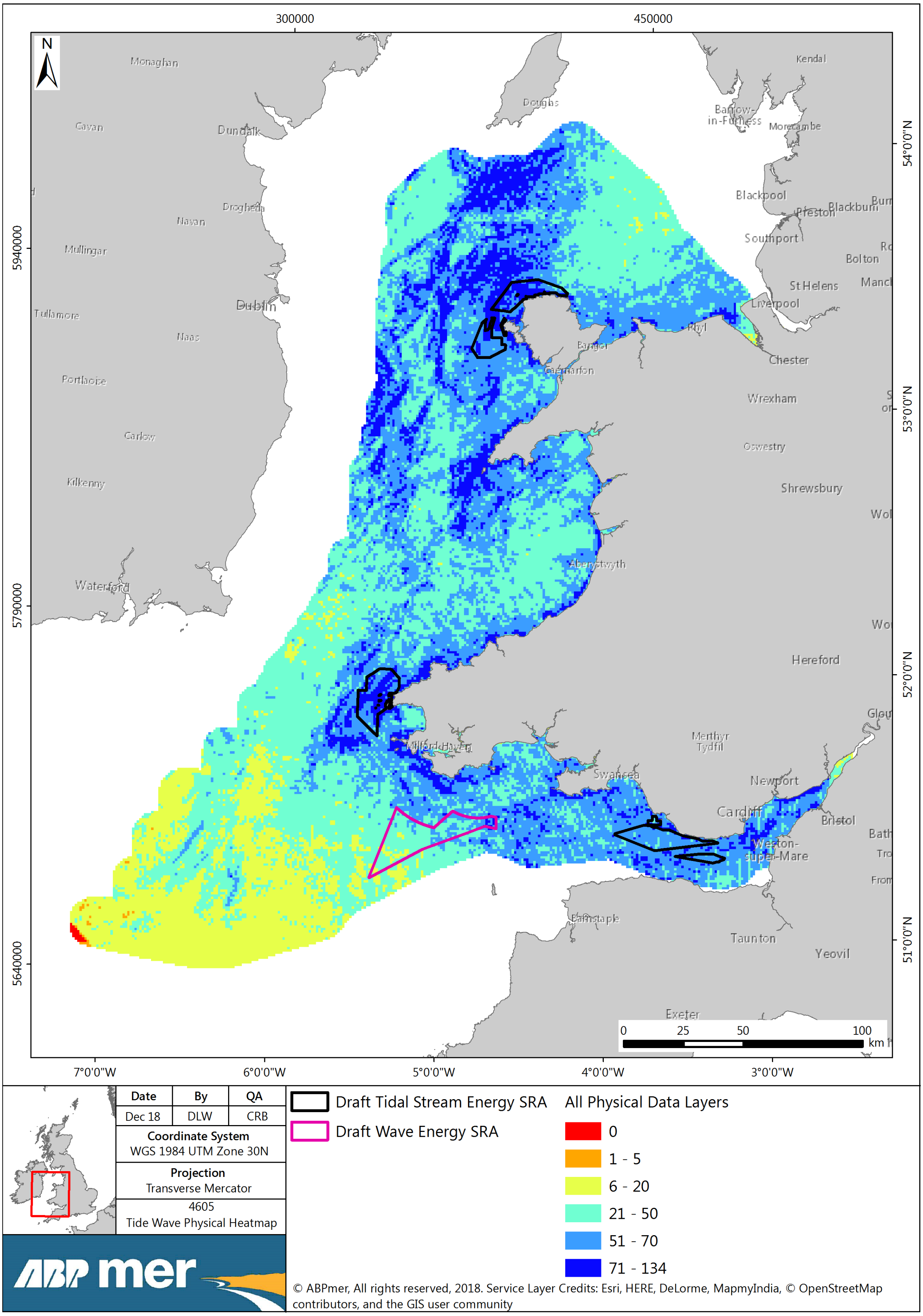


Figure 8. High scoring physical data to inform tidal stream and wave energy developments (relative data density per km²)

Chemical

Some chemical data layers were assessed as high scoring layers. Most of these will not be important for site selection of wave and tidal devices, however, the Radioactivity Monitoring Programme data layer, which monitors radioactive substances in seawater, may be important to consider. Other layers may however be important for defining baseline conditions. Layers such as Clean Seas Evidence Monitoring Programme (CSEMP), Dangerous Substances Monitoring Programme (England and Wales) and Water Framework Directive (WFD) were considered key layers for informing baseline characterisation.

Dissolved oxygen, contaminants data and nutrient data are considered important for informing baseline and assessment of tidal stream and wave energy sites (Table 8). However, no layers specifically informing dissolved oxygen levels were sourced during the data collation exercise and limited nutrient data could be sourced. It is noted that much of the WFD cycle 2 reporting should fulfil these requirements, however, only shapefiles indicating sampling units could be sourced as part of the current project.

Spatially most chemical data is in coastal zone/ transitional water bodies. There is limited data in more offshore locations therefore limited chemical data within draft SRA areas (Figure 9). However, chemical data are not typically of major concern of wave or tidal impact assessments and therefore not considered high priority data gaps.

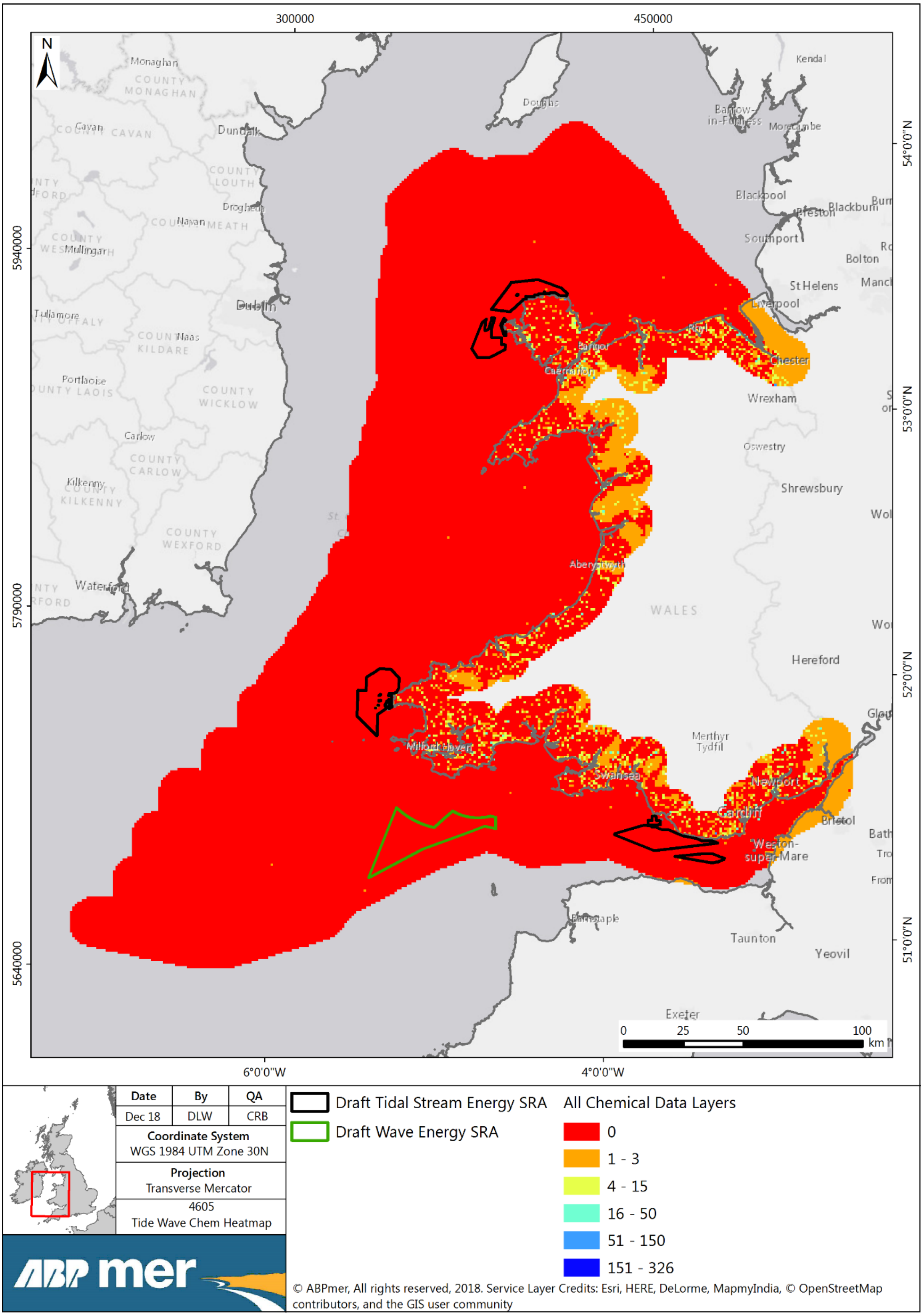


Figure 9. High scoring chemical data to inform tidal stream and wave energy developments (relative data density per km²)

Biological

Many biological data sets, especially relating to benthic habitats and species, were identified during the data collation exercise. For example, priority habitats of Wales, intertidal monitoring data, and data from Article 17 reporting. There were considerably fewer layers considered high scoring for site selection than for baseline and assessment. The key layers identified were, EU Sea Map Atlantic Habitats, EUNIS Habitat Map, MESH Atlantic, Habitat Mapping for Conservation and Management of the Southern Irish Sea (HABMAP), and HABMAP Predictive Habitat Maps of the Irish Sea. However, these layers are largely predictive, and don't show the real coverage (including extent and condition) of protected features.

However, the applicability of many of the data layers to marine planning or to specific selection of sites for installation of tidal stream or waves devices is likely to be limited. Many consenting processes require benthic sampling to be undertaken to specifically assess the impact of new developments to a site and therefore much of the data sourced is only locally applicable and likely to only provide contextual information. Additionally, due to temporal variation in benthic habitats biological datasets may become out of date within several years. This can therefore pose a large gap in data and maintaining in-date biological data can be time consuming.

Limited data was available on the presence of non-native species which could also be important for both site selection and baseline/assessment. The high scoring layer defined for non-native species distribution was prepared by the Non-native Species Secretariat.

The majority of high scoring data layers relating to fish were on the distribution of migratory species including Shad and Lamprey. Only one layer on the distribution of fish species was considered high scoring, this was the Western Approaches International Bottom Trawl Groundfish Survey - Qtr 4, which indicated a large data gap. Caution must be taken when utilising data on highly mobile species for proposed developments. High mobility of species means that distribution can vary temporally and individual monitoring for any proposed development will likely have to be undertaken. The distribution of fish species is considered key for baseline and assessment of potential developments (Table 8) and could be used, for example, to inform collision risk assessments.

Data on nursery and spawning areas of key fish species will be particularly important for informing tidal steam and wave energy site selection and assessment. Fish data specifically on spawning and nursery habitats is limited with the only key resource being from Cefas data collection. However, more recent data will be needed for future assessments, and to inform wider marine planning activities.

Only one layer relating to shark distribution, MSC Basking shark project, was identified through the data collation exercise. Although this data is relatively recent, including records from 2016, the layer was not considered high scoring and therefore not a key layer for aiding baseline and assessment at tidal stream or wave energy sites. Literature sources such as Ellis *et al.*, 2004 can provide maps for the distribution of sharks around the British Isles, however the spatial data could not be sourced for this project. These have, however, been captured within the literature evidence in Appendix D.

A more up to date, and more encompassing data layer (i.e. all known shark species distributions) would be more applicable for planning purposes. There is potential to fill this gap through mapping of species data from NBN Atlas and from the literature e.g. Ellis *et al.*, 2004. A layer similar to Ireland's Chondrichthyes of Ireland would be useful for MSP. This is especially important considering that Basking shark are a Section 7 species. Basking shark distribution are not captured within Ellis *et al.*, 2004 and are therefore a large gap.

For the distribution of marine mammals, only cetacean data was assessed as high scoring, no layers on the distribution of seals met the criteria. Data that were assessed as high scoring included data on the calving and nursey ground of harbour porpoise, marine species records from the Skomer MCZ and SCANS data.

Literature evidence (as opposed to spatial data) of seal distribution were sourced as part of the project, including grey seal distribution (Russell *et al*., 2017). Additionally, The Department of Business and Industrial Strategy (BEIS) funded a large deployment of tags on grey seals in the southern North Sea and subsequently commissioned an updated North Sea usage map reflecting the estimated grey seal population size in 2015 (Jones and Russell, 2016). These maps could fill the data gap highlighted above.

Risk of collision of marine mammals with tidal stream or wave energy devices. is considered an important impact pathway when considering tidal stream and wave energy activities. Spatial distribution and cetacean abundance data will be needed to fill this gap. It is worth noting that MERP (Marine Ecosystems Research Programme) have produced some maps on collision risk (MERP, 2017) included in the Literature evidence (Appendix D), which when made publicly available could fulfil this requirement. Additionally, it would be possible to create cetacean or seal density maps for Wales. However, currently the distribution and density maps for mobile species are generally lacking across Welsh waters to inform underwater noise assessments and collision risk modelling. Operational devices will also produce underwater noise and additional noise disturbance may be created during routine and emergency maintenance of devices from vessels. Little data was identified to address the impact of noise disturbance to cetaceans or seals and it is therefore considered an important data gap.

There was generally good data on seabird distribution with the Seabird monitoring programme and Seabirds at Sea Evidence base being defined as high scoring data layers. Both data sources will feed into both baseline characterisation and to site selection for tidal and wave devices, however, both layers still have limitations to their use. It should be noted that additional layers on seabird distribution may be available from the FAME (Future of the Atlantic Marine Environment) and STAR (Seabird Tracking and Research) projects run by the RSPB, which have organised the tracking of seabirds on the coast of Britain and Ireland from 2010 to present. This data is accessible by request to RSPB, however was not able to be soured for the current project.

However, overall layers applicable for the distribution of birds were limited, e.g. wading birds, risk mapping/ collision risk of birds with tidal stream or wave energy devices. This data could be key for informing site selection of tidal stream or wave energy devices. Data products from the MERP programme (MERP, 2017) could again be a key source of information to fill this gap. In addition, there have been several recent studies (Waggitt *et al.,* 2017a, b) on the interactions of seabirds in tidal stream areas, which could provide important information to inform site selection. However, a more comprehensive aerial survey undertaken across Welsh waters to better characterise seabird distributions and abundance would help to improve information to support planning of tidal stream/ wave energy developments.

Only six layers were sourced relating to otter distribution. All of these were highly localised and thus not really suitable for marine spatial planning. None of the layers were more recent than 2006 and therefore require updating to accurately represent otter distribution. However, there is unlikely any potential impact of tidal stream and wave energy instillations on otter populations, so this is considered a low priority data gap.

Spatially the majority of biological data is in coastal waters. However, two distinct lines reaching offshore show areas of high data availability. One area can be seen between Holyhead, North Wales, and Dublin. The other reaches between Pembroke and Rosslare, Ireland. When comparing with vessel AIS data (Figure 11) it can be seen that these two areas link closely with two major ferry routes. These high-density data areas are, therefore, likely caused by high sightings of bird and mammals during transit (Figure 10).

One large data gap can be seen to at the south western boundary of Welsh waters, between Welsh and Irish waters. This represents a large gap in data availability. Additionally, there is limited data within both tidal stream and wave energy draft SRAs, which is a significant limitation in informing site selection and informing contextual baseline descriptions and scheme assessment. There is much better coverage of biological data for the tidal stream SRA off Pembrokeshire.

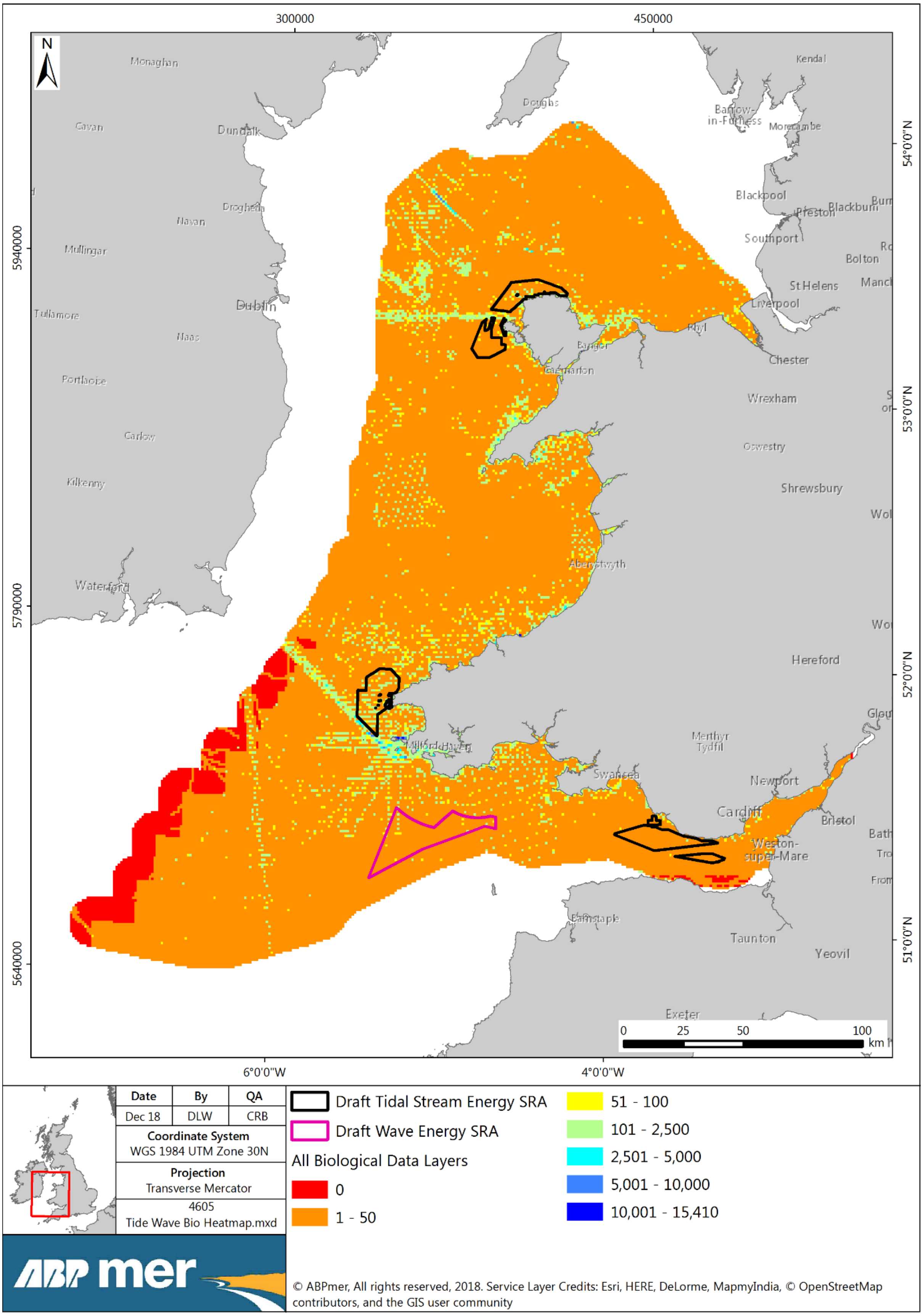


Figure 10. **High scoring biological data to inform tidal stream and wave energy developments (relative data density per km²)**

Human environment

Several layers for different sector activities which might cause conflict with tidal and wave energy site selection were considered high scoring layers. TCE All Offshore Activity UK includes data on many of the offshore energy activities including pipeline locations. Additionally, layers highlighting MMO Marine Consents, NRW marine licences, aggregate areas and key shipping routes including Automatic Identification System (AIS) tracks could be important for determining site selection.

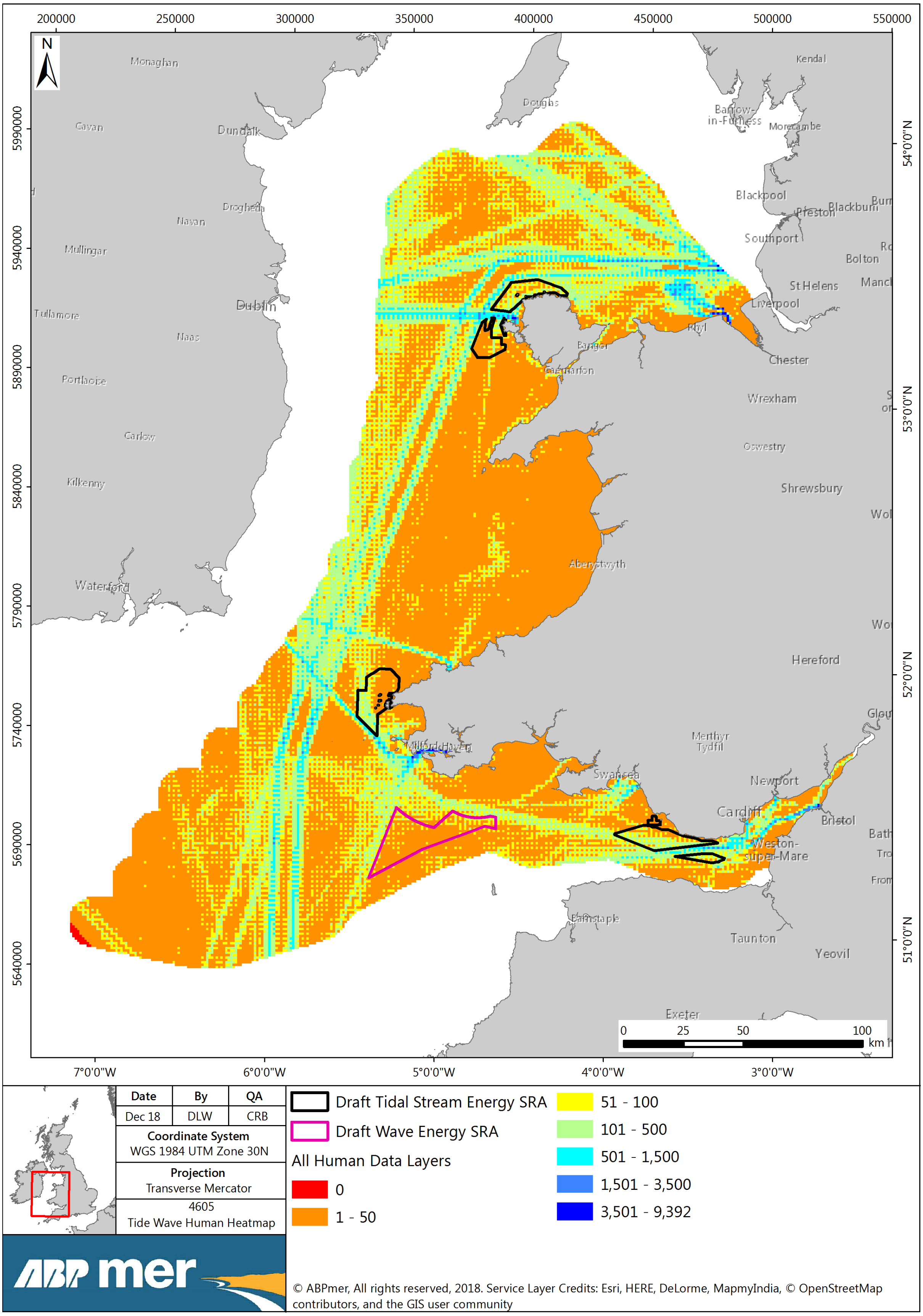


Figure 11. **High scoring human environment data to inform tidal stream and wave energy developments (relative data density per km²)**

It is Interesting to note that two of the high density biological areas correspond with vessel tracks, as noted in the biological data section above. This may be a limitation of seabird and cetacean distribution data as observational bias is influencing data distribution.

AIS track data provides a high-quality data source for informing key shipping areas. However, due to the high level of data points in AIS track data it distorts the impact of other human environment layers on the produced heat map. Figure 12 therefore provides an indication of the spatial distribution off all other human environment data, excluding AIS tracks.

Data on the human environment could be useful to inform cumulative impacts and in-combination effects. It also identifies areas of constraints and opportunities for development within Welsh waters based on relative risk mapping and activity-pressure sensitivity relationships.

Finally, layers indicating protected area boundaries further highlight conflicting areas for site selection of tidal stream and wave energy devices (see Appendix E). Although important to know the location of protected area boundaries they do not define data gaps for spatial planning so are not considered further in the gap analysis.

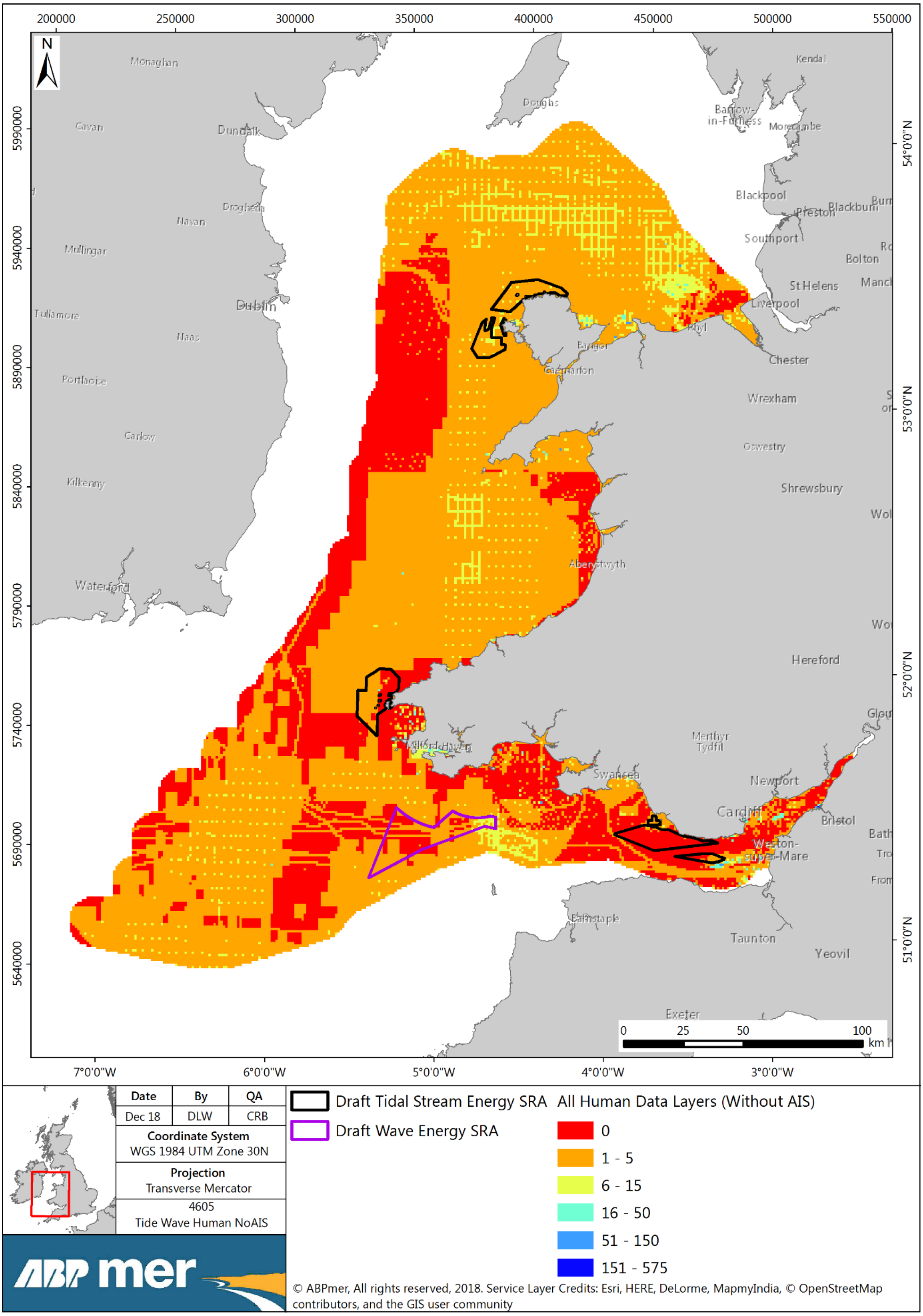


Figure 12. **High scoring human environment data, without AIS data, to inform tidal stream and wave energy developments (relative data density per km²)**

3.6.4 Aquaculture

A total of 401 data layers were identified for aiding aquaculture site selection and 278 for baseline and assessment. Of these 207 were considered high scoring layers for site selection and 160 for baseline and assessment. It should be noted that data have been considered for aquaculture as a whole, but some layers will be more appropriate for certain types of aquaculture i.e. finfish, shellfish and seaweed. Table 8 provides a breakdown of the receptors considered important for each aquaculture sector.

Physical

Physical data including bathymetry, tide and wave data, wind, substratum, sea surface temperature and salinity are all considered important for site selection of aquaculture instillations, including finfish, shellfish and seaweed aquaculture activities. Despite this there are limited data on wind and no high-quality data on salinity.

Bathymetry data, INSPIRE bathymetry archive and Digital Elevation model, were considered high scoring layers. Additionally, data on the Marine Renewables Atlas was considered high scoring and can aid in site selection for aquaculture instillations. Data on sea surface temperature (SST) can be important for assessing baseline/ assessment at aquaculture sites, the Celtic Explorer Underway data layer was the only SST layer assessed as high scoring.

In the current project, only the spatial extent of sampling units for WFD cycle 2 could be sourced, however if sourced the data collected as part of the WFD Cycle 2 programme could fill gaps in this data requirement.

Spatially, there is limited data coverage to the south west of Welsh waters and this could be considered a data gap. However, there is generally good spatial coverage of data across draft SRA areas (Figure 13).

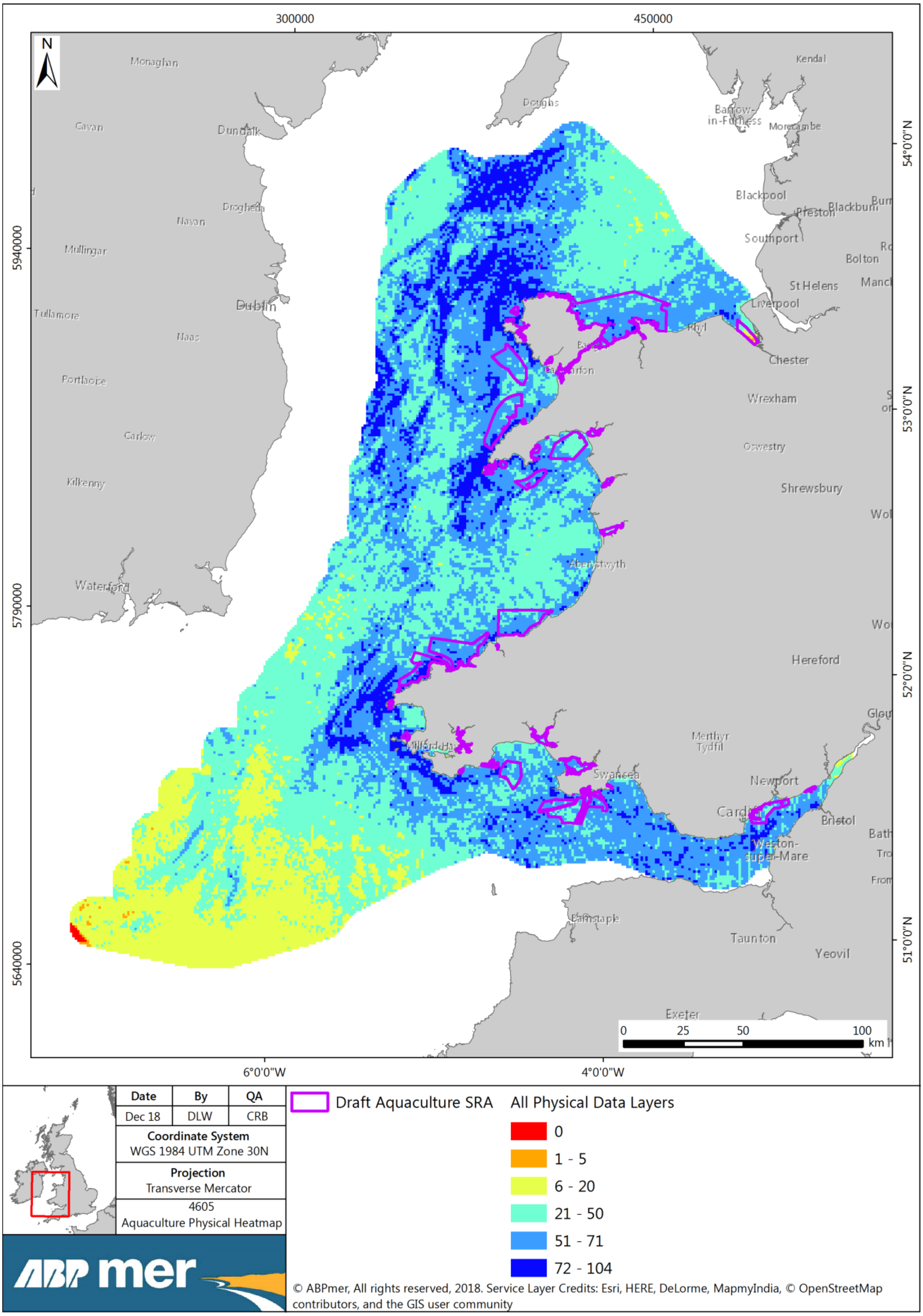


Figure 13. **High scoring physical data to inform aquaculture developments (relative data density per km²)**

Chemical

The Clean Seas Evidence Monitoring Programme provides the main source of information on contaminants. Several contaminants layers, which include toxins, dangerous substance and radioactivity were sourced as part of the project, but no dissolved oxygen layers could be sourced, nor could layers specifically relating to heavy metals.

Other layers sourced included those from the WFD Cycle 2 monitoring, which collected data on dissolved oxygen, contaminants and salinity. However, it should be noted that as it currently stands only the general sampling areas for this data could be sourced for this project, as opposed to exact locations, which, therefore, presents a data gap. Therefore, sourcing of the WFD Cycle 2 monitoring data is important to address the current data gap.

Data layers on Shellfish classification zones and shellfish waters were also identified as high scoring for shellfish aquaculture site selection and baseline and assessment. Additionally, during the data search several maps were found relating to the 'Official Control Biotoxin Monitoring Programme for England and Wales' from Cefas. Although the data for these could not be sourced for the current project, if data could be sourced, or maps digitised then this could provide an important data layer, especially with regard to aquaculture site selection.

No specific river or catchment data could be sourced, which can provide key information on nutrient loads in the water column, a receptor considered important for site selection and baseline and assessment for finfish, shellfish and seaweed aquaculture. Some information on river and catchment data has been captured within the WFD monitoring in Cycle 1 and 2 and some alongside monitoring of migratory fish species such as shad and lamprey, however no specific layers were identified during this study, indicating a gap in data requirements.

Despite limited river or catchment layers being sourced, much of the spatial spread of contaminant monitoring data has occurred within coastal and transitional water bodies (Figure 14). Spatially there is therefore a large gap in chemical monitoring in the offshore marine environment.

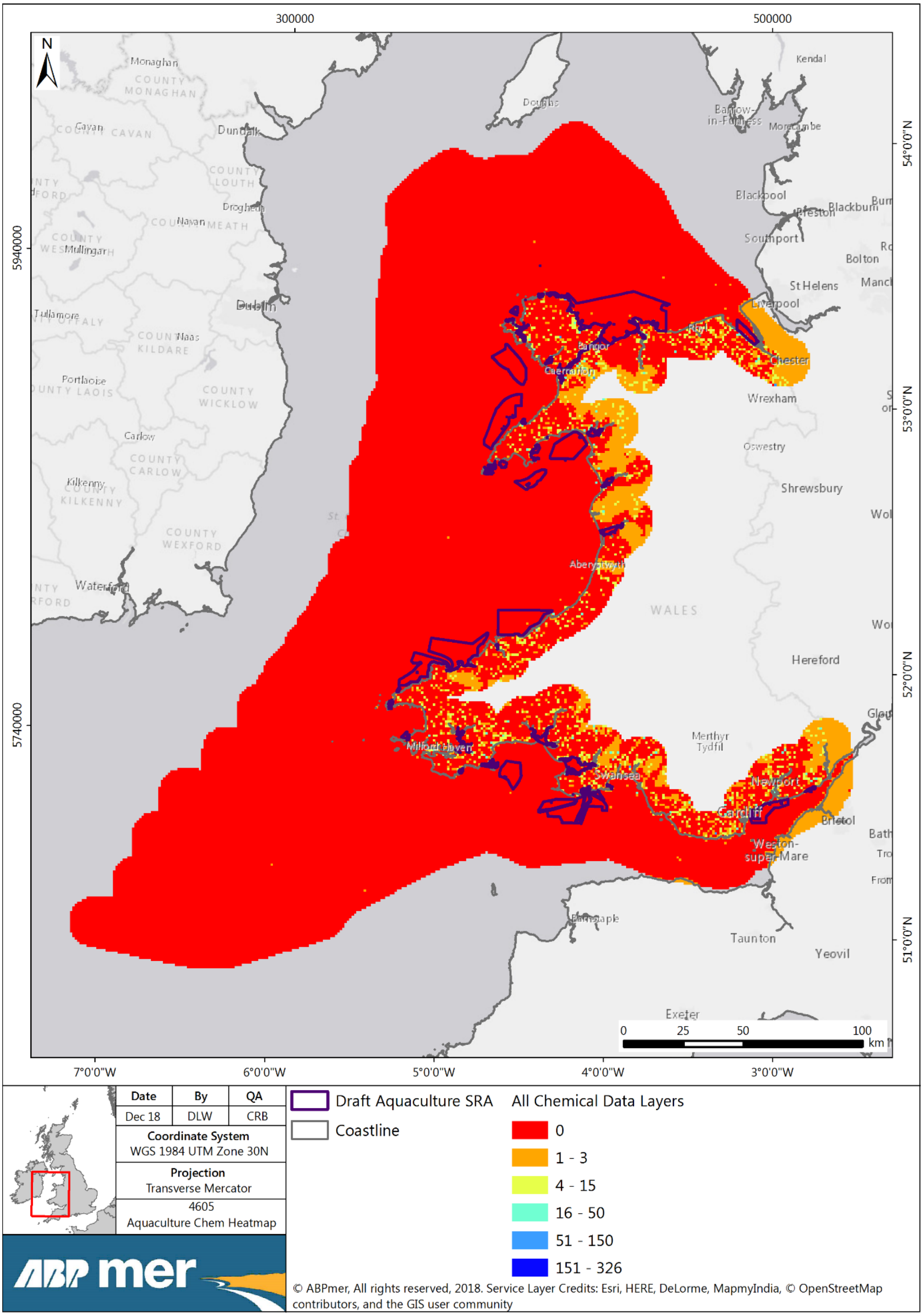


Figure 14. High scoring chemical data to inform aquaculture developments (relative data density per km²)

Biological

There were a large number of layers relating to the distribution of benthic habitats and species. High scoring layers include priority marine habitats Wales, WFD monitoring and Article 17 species and habitat data layers. Many of the layers from the intertidal monitoring programme in Wales were also considered high scoring layers.

Non-native species layers are particularly important for aquaculture as non-native species can impact activities through competition with the cultivated species, through potential spread of disease or fouling of infrastructure. Two data layers were highlighted as high scoring for information regarding non-native species distribution, the Anglesey Invasive Species: Non-native Species and *Sabellaria spinulosa* Survey 2016 and the Non-native Species Secretariat.

All of the high scoring data layers regarding fish distribution were related to migratory fish species including shad and lamprey data collected as part of the SAC monitoring programme. No data on fish distribution or nursery and spawning grounds were considered high scoring, which indicated a large data gap. Data on spawning and nursery habitats are important for site selection. The only layer sourced relating to nursery and spawning grounds was from Cefas in 2012. As these areas are defined by physical parameters they are unlikely to change quickly, however more recent data may be needed for future assessments, and to inform wider marine planning activities.

Similarly, very few layers regarding the distribution of marine mammals, including cetaceans, seals and otters were considered high scoring. The predominant layers identified were SCANS and Marine Species Records from Skomer Marine Conservation Zone (MCZ) Marine Monitoring Programme. The data collected for marine mammals was mainly related to distribution. However, as highlighted in Section 3.6.3 above, several literature sources have been collated as part of this project and these may help address this data gap.

There were very few high scoring data layers on seal distribution. This poses a particular gap for finfish aquaculture site selection, where seals could interfere with nets. It is therefore important, where possible, to update these layers.

For aiding in site selection of aquaculture installations the Seabirds at Sea Evidence base and seabird monitoring programme were considered high scoring layers regarding the distribution of seabird species, however there are limitations to their use in refining specific locations that might be more or less suited to aquaculture. No layers relating to wading bird distribution were considered high scoring which presents a large data gap as wadding bird distribution is considered important for baseline and assessment and site selection of aquaculture activities. Throughout the data collation process the only data layer sources relating to wading bird distribution was the Wetland Bird Survey (WeBS).

Spatially, aquaculture SRAs within inshore/ coastal waters have a higher coverage of biological data than those further offshore (Figure 15).

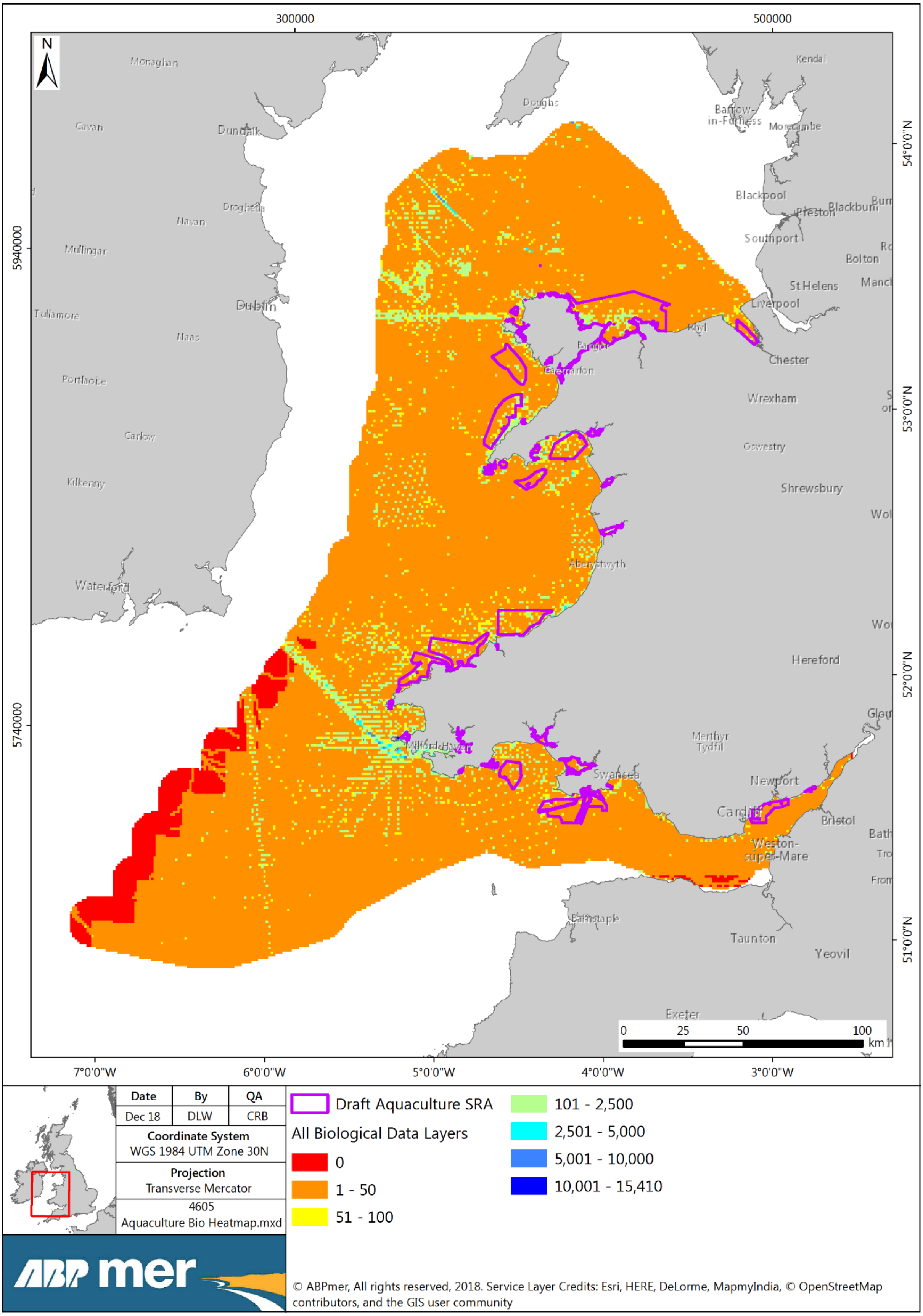


Figure 15. High scoring biological data to inform aquaculture developments (relative data density per km^2)

Human environment

Several layers for different sector activities which might cause conflict with aquaculture site selection were considered high quality layers. The TCE All Offshore Activity UK layer includes data on many of the offshore energy activities including pipeline locations. Additionally, the MMO Marine Consents data layer is also important to indicate licence areas for conflicting activities.

There is limited aquaculture and fisheries data. For example, the location of current aquaculture installations is held by Cefas but is not publicly available due to commercial confidentiality. However, theses layers would provide a useful source of information for aquaculture site selection if publicly available.

Additionally, shipping track lines and important shipping routes can be defined from AIS tracks data. Although this data was considered high scoring in this assessment, continual updating of data will be important to understand high use shipping areas. AIS data can be analysed using data processing tools (see Appendix G for more detail on tools for use within marine spatial planning).

Data on administrative boundaries, i.e. areas which might overlap with designated areas, was generally readily available and considered high scoring during the QA process. Data such as SSSI, SAC and SPA boundaries were included within the database (shown in Appendix E). However, no land ownership maps relating to the foreshore could be sourced as part of the current project and this poses a significant data gap. It should be possible, however, to obtain this data from TCE. It would therefore be beneficial for future work to create a land ownership data layer. This is particularly important for Wales as several areas e.g. Penmon point, Anglesey are privately owned and not Crown Estate land.

Finally, there was limited high scoring layers relating to tourism and recreation. The main layers were the location of marinas and RYA training centres. However, for nearshore aquaculture placement this could have an impact so additional data collation on tourism and recreational activities is recommended to inform site selection, and to aid in cumulative/ in-combination impacts. The data should also inform areas of constraint or opportunity for aquaculture site selection and potentially highlight areas where activities could co-exist.

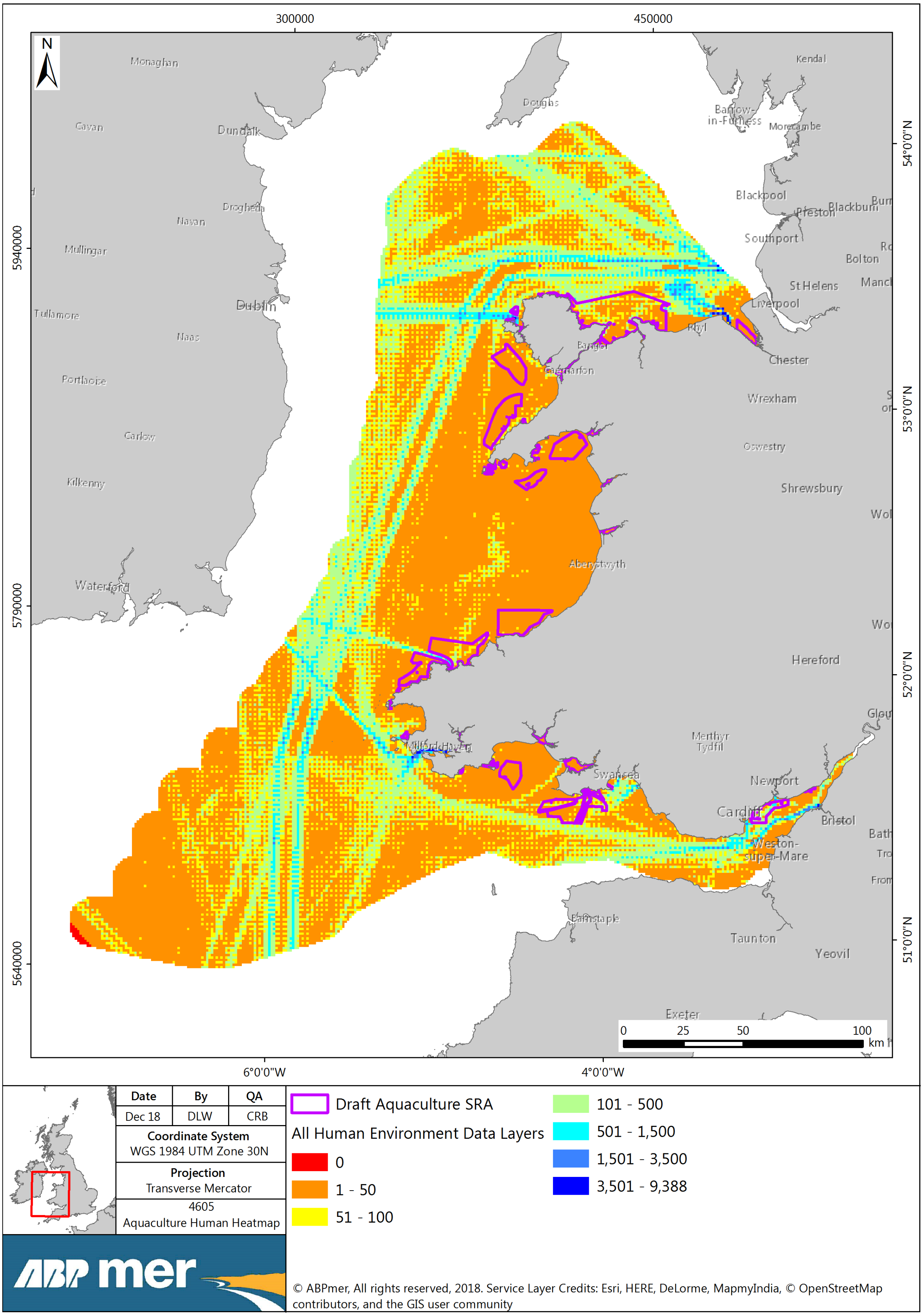


Figure 16. **High scoring human activity data to inform aquaculture developments (relative data density per km²)**

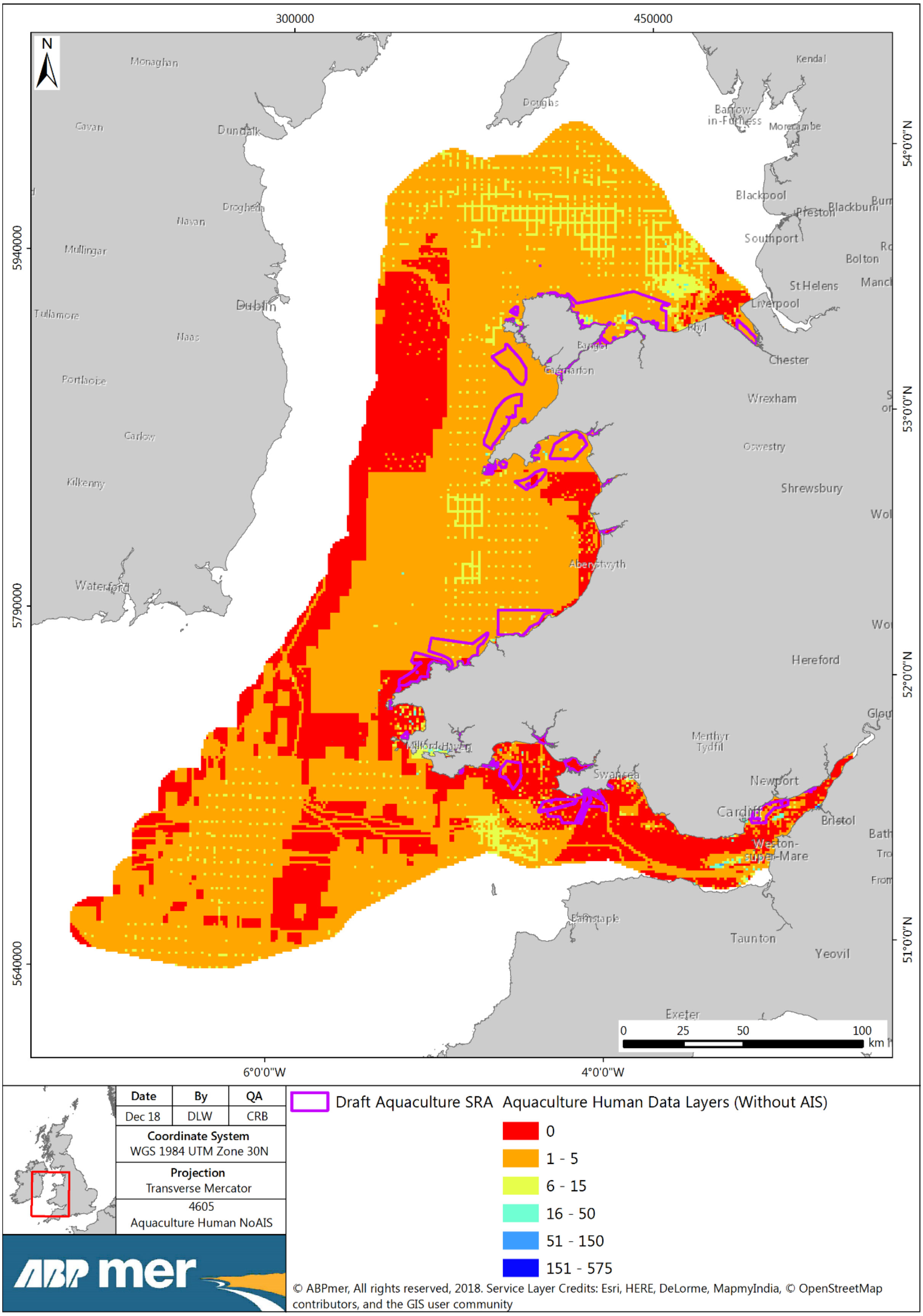


Figure 17. High scoring human activity data without AIS data to inform aquaculture developments (relative data density per km²)

3.6.5 WMPP Review

As part of the data assessment process the structure and contents of the WMPP has been reviewed to evaluate:

- Data gaps (in the context of both the data requirements of this project and wider initiatives); and
- Potential to include datasets collated as part of this project.

A wide range of data suitable for marine planning is available on the WMPP, however, a number of data gaps have been highlighted, many of which are addressed in the geodatabase provided as part of the wider project.

One of the biggest gaps is biological data within the environmental section. There is limited data on species distributions on the planning portal including; marine mammals, fish, sharks, non-native species and seabirds. This will be required for any aspect of a project lifecycle from initial marine planning to consenting and is therefore fundamental to MSP. Some examples of data currently unavailable on the WMPP include:

- No data could be found which showed the distribution of Section 7 habitats and species. This data would be required to provide better confidence in site selection and assessment of activities. This links closely to the lack of data on shark distribution, and to basking shark in particular, a Section 7 species. Limited marine mammal data for both cetaceans and seals are included on the portal. Only one data layer regarding seal haul out could be found.
- Physical and chemical data are quite sparse. The only layer relating to WFD monitoring found on the portal was WFD River Basin Districts. Addition of all WFD monitoring data from Cycle 1 and 2 could be included within the portal to address this gap.
- Although a range of seabird data are available on the portal, much of this data is from 2011 and more recent data would be needed to accurately inform consenting activities. Similarly, no data on wading birds was available on the portal.
- Data on fish distribution was not on the portal and this has been highlighted as major issue for informing the consenting process. In addition, data on the distribution of migratory species also poses a large data gap, and this would be especially important where activities may occupy constrained geographical areas e.g. tidal streams within sounds (this is especially relevant with the proposed SRA at Milford Haven). Although data on spawning and nursery habitats is on the WMPP, it is under a policy context as opposed to providing underlying environmental data.

Where environmental layers are available they often appear to be outdated and/or related to policy as opposed to presenting the underlying data. In this context there is the opportunity for greater integration between the WMPP and the Lle Geo-Portal, which furthermore could be updated with the data collated throughout the wider Sustainable Management of Marine Natural Resources project.

Other general data gaps include those that have been discussed in Sections 3.6.3 and 3.6.4 above. To further address these gaps additional data collection or modelling will be required, recommendations and prioritisation for future data collection are discussed in more detail within Section 6.

3.7 Data limitations

This section discusses the limitations to the data collation and assessment phases of the project, and where possible, makes recommendations to address these limitations.

Through a data mining exercise this project aimed to identify a comprehensive list of evidence sources to inform site selection and contextual information to inform the consenting process. Whilst every effort has been made to source all appropriate data, due to licence requirements and some data being privately held, not all data could be sourced as part of this project. Where data is known to exist, this was signposted, and where such data has potential to fill a data gap it has been highlighted where possible.

One of the largest limitations, or biggest data gaps, highlighted as part of this project is that currently no data could be sourced from post-consent monitoring. To address this gap it is recommended that, where possible, data collated from future work is captured and fed back in to the evidence base. These data could then be used to inform the assessment (and consenting) of future development.

The QA process to assess the relative quality of each of the collated datasets was based on a method adapted from the MESH confidence assessment protocol (MESH, 2007) and JNCC Protocol E (JNCC, 2012a). Whilst this assessment is as comprehensive as possible there are some potential limitations associated with its application. For example, the scoring system includes a temporal element, 'timeliness' as discussed in Section 3.4.3. As such, scores are relevant to data layers at the time of writing this report. However, if data layers are to be used for future planning or consenting the temporal score may no longer be applicable and currently high scoring layers may not meet the criteria of future assessments.
Additionally, as a consistent approach to scoring and mapping was applied to all data layers collated as part of this project there may be a limitation to the scores assigned to human environment data. Human environment data is likely to be relevant to site selection and baseline characterisation for tidal stream, wave energy and aquaculture, as activities are generally fixed and therefore scoring relating to timeliness and spatial coverage are less applicable. In future assessments of human environment data may need to be considered separately to avoid this limitation depending on the intended application of the data.

During the mapping process grids were used to overlay the data to create the heat maps. Grid cells represent where data occur within a 1 km grid and do not indicate exact location of data points. Data points within the grid may not be evenly distributed and may therefore not be as spatially accurate as is required for marine planning. This should be taken in to account if data are utilised for wider planning purposes when the underlying data should be accessed via the geodatabase. This is particularly apparent for human use data where the spatial locations of activities are generally well defined.

Finally, although a range of data layers have been assessed as high scoring following the QA process, it should be noted that this is only an indication of high scoring for the current project and may not be applicable to other uses. Although much of the data will be applicable for wider marine spatial planning (as discussed in Section 3.8 below) additional QA or assessment may need to be undertaken to evaluate the quality and confidence for use of the data for wider applications.

3.8 Wider uses of the data

Although the data collated as part of this project aimed to inform site selection and baseline characterisation of tidal stream, wave energy and aquaculture development it should be noted that the data is relevant to wider marine spatial planning and environmental reporting in Welsh waters.

The majority of the data layers collated within the database are publicly available data, which could be added to the Lle Geo-Portal. Therefore, the data collated could be used to form an important base for future data collation exercises within the Welsh marine plan area and can be added and developed over time to meet multiple objectives.

4 Specific Impact Pathways

In addition to the gaps in available datasets, there is a lack of comprehensive evidence for specific impact pathways with potential to occur as a result of the focus activities. As previously identified by stakeholders, such a lack of evidence can result in a precautionary approach to consenting and data collection, with an increase in associated costs and programme delivery (see Section 2.3). At the extreme end of the scale, the adoption of the precautionary approach may ultimately prevent consent being granted due to a lack of evidence, or low confidence in the evidence available.

These concerns were expressed by developers at the Cardiff workshop (20 April 2018) and are acknowledged by regulators as a key obstacle surrounding the consenting of emerging technologies or where large areas of uncertainty remain in the context of legislative requirements.

Consequently, this section documents evidence on specific impact pathways to help identify additional evidence gaps over and above the spatial data gaps identified in Section 3. To start to address this, the project has sought to collate and signpost evidence with respect to specific impact pathways. This has allowed data gaps to be highlighted in relation to these pathways while recognising where evidence and data sources provide a good understanding of an impact pathway. For the well-understood impact pathways, subject to no site-specific considerations, it is assumed that the consenting requirements would be clear.

Where required, evidence has been gathered from beyond Welsh waters (e.g. Scotland, Ireland, USA) to inform the understanding of the specific impacts. At a broad level, the lessons learned and outcomes from relevant research are transferable within, and sometimes across, sectors. Hence, these provide valuable information which may not be available from Wales or even the UK. At the same time, it is also recognised that site-specific factors will always be key to understanding the full impacts of a proposal.

This section of the report has initially considered the specific impact pathways where there are uncertainties and gaps relevant to each activity, the detail of which is provided in Appendices F.1 to F.4. This is followed by consideration of the potential cumulative effects of multiple activities on these pathways. The conclusions from this exercise are summarised in Section 4.4 with considerations taken forward in Section 5, while recommendations relevant to this work are discussed in Section 6.

4.1 Approach

4.1.1 Specific impact pathways

An impact pathway is the exposure of a feature to a pressure and is related to the sensitivity of a given feature to the pressure. Understanding the sensitivity and exposure of a feature ultimately allows the significance of an impact to be evaluated (Figure 18).

Impacts on a feature can occur during the construction, operation and decommissioning phase of a development. Construction phase impacts in the marine environment are often considered the most likely to result in a significant impact and are therefore an important consideration for the assessment of any project. The magnitude of change is dependent on variables including size, intensity, location, extent, duration and methodology of a given activity. Construction phase impacts are generally easier to quantify than those that occur in the operation phase. For example, permanent loss of a feature under the direct footprint of a development is directly related to the area of the footprint. These impacts, while relevant, are generally well understood in terms of impact assessments, being common to all types of marine development and therefore evidence on the potential effects from these pathways is readily available. Ultimately, the consenting risk from impact pathways during the construction phase is dependent on the site and project specifics rather than the uncertainty or unavailability of evidence to support the assessments.

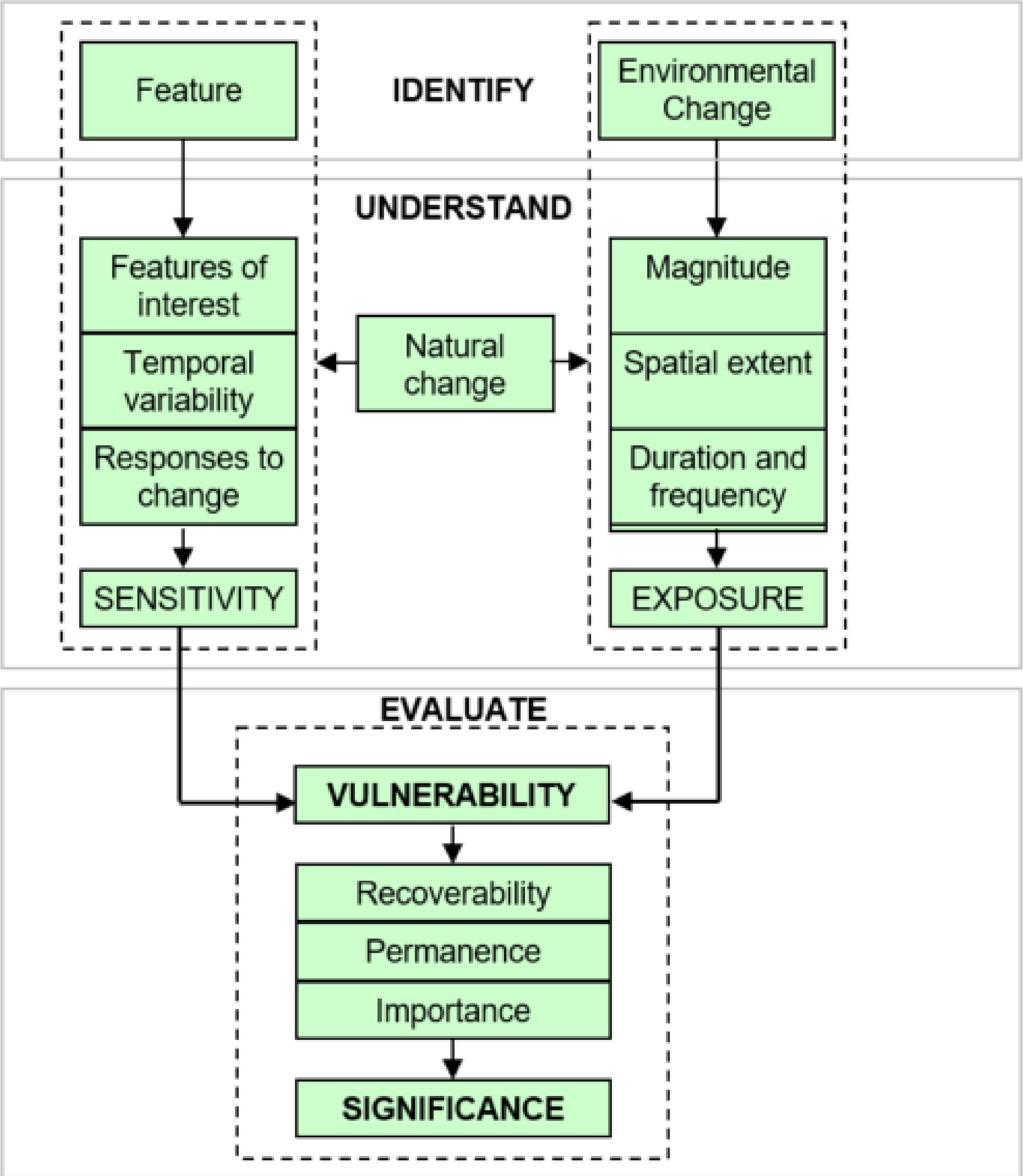


Figure 18. The impact pathway: sensitivity and exposure of a feature to a pressure

Accordingly, the list of impact pathways for each of the focus activities has been rationalised to produce a list of 'specific impact pathways' for more detailed consideration. For the most part, this has resulted in impact pathways related to the construction phase being screened out, these largely being a product of the construction methodology and site specifics. However, these are a critical consideration to any development.

The specific impact pathways covered below (Section 4.2) are largely an aspect of a focus activity's operation and, being less well documented, have a degree of uncertainty that can result in greater consenting risk. Many of the pathways are reliant on predictive assessments, such as modelling, rather than empirical evidence from developments relevant to the focus activity. The final list of pathways taken forward is derived from the outcomes of NRW and stakeholder meetings (see Appendix A).

The objective of this exercise was to investigate the specific impact pathways and signpost to key literature and evidence. Although this is not a detailed literature review, the work has highlighted the key gaps in the available evidence base while providing recommendations on how these gaps can be filled and confidence in the evidence base increased.

The evidence review has included consideration of the most recent assessments, published and grey literature, as well as post-consent and post-construction monitoring data where it is available. It has built upon work being undertaken in related initiatives such as ORJIP and previous sectoral reviews.

Key evidence literature and case examples identified for each impact pathway are provided in the appendices (Appendix F.1 to F.4), along with evidence limitations and uncertainties. Section 4.2 provides a summary of the evidence review exercise including recommendations for each pathway and an overarching consideration of cumulative impacts.

4.2 Specific impact pathways

A description of the specific impact pathways for each focus activity (tidal stream energy, wave energy and aquaculture) is provided below (Sections 4.2.1 to 4.2.3) along with recommendations addressing evidence gaps and/or limitations to the evidence base.

While the list of impact pathways for tidal stream and wave energy technologies are essentially the same, the nature of the effects and the evidence available are often different. Hence, the specific impact pathways were detailed separately for these activities with some cross-referencing where appropriate.

4.2.1 Tidal stream

The following impact pathways have been considered:

- Indirect effects on marine features resulting from changes to physical processes;
- Collision of mobile marine features resulting in injury or mortality;
- Barrier effects to fish and mammal movements or migrations;
- EMF emissions and their effect on sensitive species and
- Effects of underwater noise on mammals and fish during operation.

Indirect effects on marine features resulting from changes to physical processes

Operation of tidal turbine(s) will result in the removal of energy from the hydrodynamic system. The presence of the turbine(s) will also change the local hydrodynamics.

This pathway will change local currents and sediment transport, with the potential to also affect wave climate. Resultant effects from changes to hydrodynamics have the potential to affect the sediment transport regime and hence morphology of seabed and coastal features. Changes to flow direction and velocity also have the potential to affect water quality; such as through changes to suspended sediment concentrations.

Changes to flow regimes within estuaries is a particular concern due to their influence on tidal flushing, potential wave propagation and sediment budget. Changes in tidal flushing can change the sediment dynamics and may lead to changing patterns of deposition and erosion.

Indirectly, the changes in hydrodynamics and sediment transport can lead to changes in community composition and habitat type.

Remarks and recommendations

Review of case examples and scientific studies has provided minimal empirical evidence on the potential effects on physical processes from tidal turbines (Appendix F.1). The multitude of variables associated with each proposal (e.g. hydrodynamics, sediment transport regime, size of turbine, number of arrays) means there is unlikely to be existing evidence or data available that would negate the requirement for rigorous baseline data collection and detailed hydrodynamic modelling for a given tidal stream proposal.

However, confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the refinement of models and future modelling studies.

Irrespective of the pre-existing data and evidence there will always be uncertainties of the potential effect on physical processes and the resultant indirect effect on marine features. Understanding the potential effects requires complex predictive modelling which, through collection of monitoring data, can provide increasing confidence in the results.

Collision of mobile marine features resulting in injury or mortality

Collision of marine mammals, fish or diving birds with tidal turbines has the potential to result in injury or mortality

Remarks and recommendations

Observations from case studies have recorded minimal instances of injury or mortality to fish and no instances to marine mammals or birds (see Appendix F.1) from tidal turbines. However, the scarcity of examples at present does not provide enough confidence to move away from the precautionary approach i.e. collision risk modelling as informed by baseline surveys to identify density and utilisation by the mobile feature in question. In the case of seabirds, the standard requirement is often two-years' worth of baseline data.

In Wales, scoping opinions received in 2018 in relation to tidal stream proposals at Bardsey Island (Enlli Tidal Energy Scheme) and Fishguard (Transition Bro Gwaun Tidal Energy Development), have advised that collision risk modelling (particularly for birds) needs to be considered to inform the assessments.

The outputs of current collision risk models are primarily derived from density metadata indicating utilisation by a given feature at a location. However, a recognised limitation is that these models do not generally account for avoidance behaviour of birds, fish and mammals and thus it is difficult to assess the level of exposure to collision risk pressure.

Collection of more empirical evidence, potentially through post-consent and post-construction monitoring, is required to quantify avoidance behaviour of birds, fish and mammals and inform future collision risk models. Better understanding of the behaviour, such as avoidance, of sensitive mobile features may allow developers to move away from collision risk models.

The current requirement for up-to-date density datasets can lead to lengthy baseline work, such as seabird surveys. Pooling data on bird density, distribution and utilisation from studies carried out for commercial sectors would enable a longer-term picture of variability in bird density. This may reduce the requirement for time rich baseline surveys.

Barrier effects to fish and mammals

The physical obstruction of species movements locally (within and between roosting, breeding, feeding areas) and regional/global migrations.

Remarks and recommendations

There is scarce evidence available on the potential barrier effects of tidal arrays; however, understanding of the effects can be inferred, to some degree, from those studies carried out on collision (see Appendix F.1). Case examples at Strangford Lough and Fall of Warness indicated that mammals and fish were still transiting through the area. In the USA (Roosevelt Island Tidal Energy (RITE) Project Demonstration; Ocean Renewable Power Company Cobscook Bay Tidal Energy Project), studies of fish behaviour have indicated some general avoidance behaviour but with continued passage around the turbines.

Most commercially operational tidal devices are either single turbines or comprised of small arrays. The available evidence suggests that single devices or small arrays do not present a significant barrier to movement. However, as arrays increase in size barrier effects may become more significant. It may be possible to manage such effects through adaptive management.

Collection of more empirical evidence, potentially through post-consent and post-construction monitoring, is required to quantify avoidance behaviour of fish and mammals and inform future assessments.

Data on the key migration routes for species (e.g. Atlantic salmon, European eel) would be useful to developers at the site selection phase to understand, for example, if the proposal is located within a key migratory corridor. Data on key feeding, breeding and spawning areas should also be identified.

It is recommended that specific consideration of barrier effects is given to those proposals in geographically constrained locations. For example, a scoping opinion provided by NRW in November 2018 in relation to tidal stream proposals at Bardsey Island (Enlli Tidal Energy Scheme), advised that barrier effects to fish and mammals are considered in the assessment.

EMF emissions and their effect on sensitive species

Localised electric and magnetic fields, associated with operational power cables and telecommunication cables, have the potential to affect the behaviour of sensitive marine species

Remarks and recommendations

Evidence, though scarce, indicates that measurable effects from EMF can occur on sensitive fish species (e.g. elasmobranchs) and benthic invertebrates (Appendix F.1). Work by Hutchison *et al.* (2018)

indicated that EMF from HVDC cables (≥300 MW) resulted in a behavioural response by elasmobranchs and crustaceans; however, the response was considered minor and did not represent a barrier to movement.

Highlighting the findings from studies such as Hutchison *et al*. (2018) to regulators and stakeholders may reduce requirement for assessing potential impacts from EMF for small scale tidal developments and therefore move away from the precautionary approach. Further evidence is required to understand if large developments and multiple subsea cables with higher power ratings have the potential to result in greater effects, such as barriers to movement, on marine species.

Effects of underwater noise on mammals and fish during operation

The potential effects on mammals and fish from operational noise of tidal arrays may manifest as auditory masking, disturbance and/or barrier effects. Although noise generated would be less than construction activities such as piling, the increase in noise will be longer term and continuous

Remarks and recommendations

The potential for acute effects (injury and mortality) on mammals, fish and diving birds during operation is unlikely (Appendix F.1). However, the potential for chronic effects such as auditory masking and disturbance is not well understood.

Scoping opinions issued in 2018 for proposed tidal arrays in Wales (i.e. Enlli Tidal Energy and TBG projects) have requested consideration of operational noise effects on fish, mammals and, in the case of TBG, diving birds. Underwater noise modelling in conjunction with current and accepted scientific literature on noise thresholds for various features are required.

Considering the varied scope of potential tidal arrays and the different technologies emerging there is no evidence available that could be consistently applied with confidence in the assessing of potential effects. Hence, allowances for the multitude of variables can only be addressed through predictive modelling to understand noise generation and propagation.

Confidence in underwater noise models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

4.2.2 Wave energy

The following impact pathways have been considered:

- Indirect effects on marine features resulting from changes to physical processes;
- Collision of mobile marine features resulting in injury or mortality;
- Barrier effects to fish and mammal movements or migrations;
- EMF emissions and their effect on sensitive species; and
- Effects of underwater noise on mammals and fish during operation.

Development of the wave energy industry is at a much earlier stage than tidal stream energy. As such there are very limited case examples that are relevant to the identified pathways (see Appendix F.2). Instead the evidence is generally reliant upon scientific literature, either specific to wave energy or generic to the impact pathways being considered.

Indirect effects on marine features resulting from changes to physical processes

Operation of the wave energy device(s) will result in the removal of energy from the hydrodynamic system. This pathway will change wave climate with resultant changes on local currents and potentially sediment transport. Should changes to sediment transport regime occur there is potential to affect the morphology of the seabed and coastal features.

Changes to wave climate, flow direction and velocity also have the potential to affect water quality such as through changes to suspended sediment concentrations.

Indirectly, the changes in hydrodynamics and sediment transport can lead to changes in community composition and habitat type.

Remarks and recommendations

As an emerging technology there is scarce empirical evidence of the potential effects from this pathway (Appendix F.2). Consideration of the multitude of variables can only be addressed through predictive modelling (hydrodynamic and sediment transport) to assess the potential effects from changes on physical processes.

Confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

Infrastructure associated with the installations (foundations / anchoring points) may change flows in the immediate area of the wave energy devices; however, resultant spatial extent of these changes (e.g. on sediment transport) is likely to be highly localised.

Collision of mobile marine features resulting in injury or mortality

The presence of wave energy devices has the potential to result in injury or mortality to marine mammals and fish

Remarks and recommendations

The limited evidence on the potential collision risk from wave energy devices suggests that collision impacts to marine mammals or fish are low risk (Appendix F.2). As a surface water technology rather than located mid-water or on the seabed (i.e. tidal turbines) it is less likely to pose a risk to collision as compared with tidal arrays.

Empirical evidence is required from monitoring studies to provide greater confidence in assessment predictions.

Barrier effects to fish and mammal movements or migrations

The physical obstruction of species movements locally (within feeding areas) and regional/global migrations.

Remarks and recommendations

There is scarce evidence available on the potential barrier effects of wave energy devices; however, understanding of the effects can be inferred from those studies on collision risk (Appendix F.2). As a surface water technology, rather than located mid-water or on the seabed (i.e. tidal turbines), it is less likely to pose a risk to movements of fish or marine mammals compared with tidal arrays.

Empirical evidence required from monitoring studies to provide greater confidence in assessment predictions.

EMF emissions and their effect on benthic communities and sensitive species

Localised electric and magnetic fields, associated with operational power cables (inter-array and export cables), could potentially alter behaviour and migration patterns of sensitive species.

Remarks and recommendations

Evidence, though scarce, indicates that measurable effects from EMF can occur on sensitive fish species (e.g. elasmobranchs) and benthic invertebrates (see Appendix F.2). Work by Hutchison *et al.* (2018) indicated that EMF from HVDC cables (≥300 MW) resulted in a behavioural response by elasmobranchs and crustaceans; however, the response was considered minor and did not represent a barrier to movement.

Further evidence is required to understand if large developments and multiple subsea cables with higher power ratings have the potential to result in greater effects, such as barriers to movement, on marine species.

Effects of underwater noise on mammals and fish during operation

The potential effects on mammals and fish from operational noise of tidal arrays may manifest as auditory masking, disturbance and/or barrier effects. Although noise generated would be less than construction activities such as piling, the increase in noise will be long-term and continuous.

Remarks and recommendations

Evidence, though scarce, suggests that the effects of operational underwater noise on fish and mammals would be minimal (Appendix F.2). However, considering the varied scope of potential wave energy devices and the different technologies emerging, at this time there is no evidence available that could be consistently and confidently applied to understand the potential effects from underwater noise. Hence, allowances for the multitude of variables can only be addressed through predictive modelling to understand noise generation and propagation.

Confidence in underwater noise models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

4.2.3 Aquaculture

At the time of writing there is no commercial culture of finfish or seaweed within Welsh waters. Shellfish aquaculture represents the only commercially practised aquaculture activity in Wales, with the majority of active developments located around the Menai Strait in North Wales. However, assuming that finfish aquaculture will develop in Wales, specific impact pathways have been considered.

The lack of any commercial seaweed farms in the UK, historically or presently, means that considerable uncertainties exist on the level of assessment required for this type of proposal in relation to the marine licensing process. Consequently, until guidance is updated to capture this emerging aquaculture activity there are substantial deterrents to the development of this type of farming within Welsh waters.

Scarce information exists on the potential environmental effects of seaweed farming inshore and offshore. As part of the SeaGas project a review of the environmental considerations was carried out (Wood *et al.,* 2017). The review encompasses the potential impact pathways; however, recognising the dearth of evidence on the effects of this activity, the requirements for guidance from regulators and the large knowledge gaps, as identified within Wood *et al*. (2017), a full evidence base review has not been carried out within this report.

As noted in Section 4.1, the objective of the evidence review is to consider impact pathways specific to a focus activity and which, due to uncertainty, may increase the level of consenting risk. While it is acknowledged that there are a number of constraints to aquaculture development (see Section 2.3.3, these mostly encompass site specifics.

Finfish

The following impact pathways have been considered:

- Discharges (particulate waste, chemicals) and impacts on water and sediment quality and benthic habitats
- Transfers of pathogens and parasites to wild fish populations
- Genetic interaction between escapees and wild fish populations
- Management of predators (seals)

As a generic recommendation to the development of finfish aquaculture in Welsh waters and informing the evidence in relation to the impact pathways outlined, the conclusions of peer-reviewed research and ongoing monitoring studies in Scotland should be acknowledged. Gaps identified in the evidence base have been highlighted in Scottish waters and recognition of these will provide greater understanding to developers of the potential hurdles to consenting.

Existing Scottish legislation and guidance (Appendix F.4 and Appendix H) prevents or reduces operational impacts of finfish farming and these will assist Welsh development of this industry. Lessons learned from recent evidence reviews of fish health and environmental challenges in Scotland, and development of new regulatory frameworks (e.g. SEPA's draft finfish aquaculture sector plan) and modelling tools to understand the impact of fishfarm discharges on the seabed and assist with site selection (NewDEPOMOD) will be particularly important.

Discharges (particulate waste, chemicals) and impacts on water and sediment quality and benthic habitats

Operation of fish farms results in discharges including solid wastes (i.e. uneaten food and faeces from cages), dissolved nutrient inputs and medicines/chemicals (for treatment of parasites, antimicrobials and trace metals). Fish farm organic waste accumulating on the seabed can significantly degrade communities of benthic animals beneath or near farms whilst significant enrichment of enclosed bays, inlets and regional seas by fishfarm nutrients could lead to enhanced growth of phytoplankton, with impacts on marine communities and water quality. Synthetic chemicals (including antibiotics) used to treat lice infestation or salmon diseases, to prevent fouling of marine structures, or as dietary supplements, may impact on other organisms.

Remarks and recommendations

It is recommended that Welsh regulators, developers and stakeholders use modelling tools such as NewDEPOMOD[3] to understand the impact of fishfarm discharges on the seabed and assist with site selection.

Transfers of pathogens and parasites to wild fish populations

Transfer of disease (e.g. Infectious Salmon Anaemia) and parasites (e.g. sealice) from farmed stock to wild fish populations. The presence of large numbers of fish within a farm provides a favourable habitat for the growth and spread of pathogen and parasite populations. Depending on the mode of infection, water currents may spread pathogens between farms and potentially between wild and farmed populations.

Remarks and recommendations

There is evidence to suggest that sealice are becoming increasingly resistant to chemical treatments which may also correlate to increases in sealice observed on wild fish. Further evidence is most likely to arise from Scotland via ongoing and future monitoring data and research.

Genetic interaction between escapees and wild fish populations

Farmed fish escapees may interbreed with wild fish populations, harming the gene pool of wild salmonid stocks. Such an impact could affect the long-term health of wild salmonids.

Remarks and recommendations

In Norway, gene flow from escapees to wild salmon has been shown to change smolt maturation age and size which may affect the populations adaptiveness to conditions in their native rivers. However, there is little information currently regarding the extent of such genetic mixing in Scottish salmon (SAMS, 2018). Further evidence is most likely to arise from Scotland via ongoing and future monitoring data and research.

Management of predators (seals primarily)

Disturbance to marine mammals and birds from non-lethal deterrents (e.g. netting, acoustic methods) used for management of predators. Potential impacts may include entanglement in netting or behavioural changes caused by use of underwater Acoustic Deterrent Devices (ADDs) on seals or cetaceans.

Remarks and recommendations

Better reporting of ADD usage and increased understanding of ADD efficacy and impact could help assess and manage the trade-off between predator deterrence (i.e. seals) and noise pollution effects, including on sensitive marine mammals (e.g. cetaceans). Further evidence is most likely to arise from Scotland via ongoing and future monitoring data and research. The use of cetacean friendly ADDs should be considered.

Shellfish

The following impact pathway has been considered:

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3 DEPOMOD Modelling Software developed by SAMS. Available online at: https://www.sams.ac.uk/science/projects/depomod/

Introduction of invasive non-native species

Introduction and spread of invasive non-native species (INNS) can occur through the transfer of aquaculture stock (e.g. the movement of shellfish spat/seed between the area of collection to the on-growing site). Depending on the INNS introduced and the characteristics of the site, the INNS can become established.

Remarks and recommendations

The issue of INNS is well recognised within the UK with a number of mechanisms, across many sectors, implemented to prevent the introduction and spread of INNS (Appendix F.3). Within England and Wales the following legislative requirements relating to the preventing the spread of finfish and shellfish disease and INNS apply to aquaculture developments:

- The requirement for all Aquaculture Production Businesses (APBs) to be authorised by the Fish Health Inspectorate (FHI), Cefas to operate and import livestock under the Aquatic Animal Health (England & Wales) Regulations 2009.
- Requirement for aquaculture operators intending to undertake the introduction of an alien species or the translocation of a locally absent species to apply for a permit from FHI under The Alien and Locally Absent Species in Aquaculture (England & Wales) Regulations 2011 (where not exempted in Annex IV).

The Code of Good Practice (CoGP) for mussel seed movements[4], produced by the Welsh shellfish industry in 2008, indicates a well-developed understanding of the potential issues of INNS and how to reduce the risk within this type of aquaculture. The CoGP makes provision for unfamiliar species, these potentially representing INNS, and the requirement for continual vigilance, acknowledging that the Code may need to be adapted as understanding of marine INNS increases. Recent studies have identified species that are considered priority marine INNS[5] in Welsh waters. Ensuring regular communication to the Welsh aquaculture industry will allow producers and developers to adapt the Code, if required, and be informed on the latest understanding of marine INNS. Marine biosecurity planning guidance covering Wales and England (Cook *et al.*, 2014), provides general guidance for commercial and recreational users towards controlling the introduction and spread of marine INNS.

An inherent limitation to reducing the potential of this impact in any sector is the recognition of an INNS. Some species are cryptic in appearance e.g. *Didemnum vexillum* and not easily differentiated from congeneric species while others may be unfamiliar if new to Welsh waters. The CoGP also makes provision for 'pest identification cards' to allow workers to identify key marine INNS. Updating these cards to align with those on the Welsh priority marine INNS will continue to reduce the risk from inadvertent introduction of marine INNS in shellfish aquaculture operations.

4.3 Cumulative Impacts

For the purposes of this section, cumulative impacts are considered as the potential for an in-combination effect on a specific impact pathway resulting from a) multiple arrays/farms of the same focus activity; or b) where two or more different focus activities are proposed.

4 Bangor Mussel Producers Association, (2008). Code of good practice for mussel seed movements. Version 1: July 2008 Available online: https://www.nw-ifca.gov.uk/app/uploads/Code-of-Good-Practice-seed-mussel-movement.pdf

5 Marine Invasive Non-native Species: Priority Monitoring and Surveillance List for Wales. Published January 2018. Available online: https://beta.gov.wales/sites/default/files/publications/2018-02/invasive-aquatic-species-priority-marine-species.pdf

The considerations for spatial planning and the potential consenting risks for developers and regulators where draft SRAs and activities (focus or otherwise) are proposed in the same geographical region are discussed in Section 5.

4.3.1 Multiple developments (tidal/wave energy)

Most of the evidence available on the identified impact pathways has been collected in relation to single devices or small arrays which are generally short in duration (from several months to just over a year). While the data and evidence are useful from these test sites, there is considerable uncertainty as to whether multiple arrays would pose a significant or greater risk to features.

The site-specific qualities and technology employed will have a considerable bearing on the potential cumulative effects and therefore a case by case approach will need to be employed. However, in all cases the likelihood of a potential significant effect from the pathways identified is increased.

Upscaling of the potential effects from single devices to multiple arrays is not straightforward and will require additional effort, investigation and monitoring to determine whether large arrays of devices may present an increased risk to marine features. For example, assessing the effects of changes to hydrodynamics relies on predictive modelling. Where confidence in the modelling is limited and/or there is potential for affecting a sensitive and important feature (e.g. Annex I habitat) the complex modelling required to assess cumulative impacts arising from multiple devices would increase the level of consenting risk.

There are currently two demonstration zones in Wales, the West Anglesey Demonstration Zone managed by Morlais and the South Pembrokeshire Demonstration Zone managed by Wave Hub; these zones representing testing areas for tidal and wave energy devices respectively.

Elsewhere around the UK there are tidal and wave demonstration zones at Harris, Islay, North Cornwall and North Devon.

Marine Energy Wales is developing a Marine Energy Test Area (META) project in and around the Milford Haven Waterway. The META project proposes a number of sites within the same broad geographical area to test wave and tidal devices.

Once devices are deployed, monitoring the effects on the environment will provide evidence for future assessments and validation of modelling outputs. Assumptions on the additive or multiplicative effects from multiple devices and/or activities will need to be validated with field data to provide greater confidence in assessments and reduce consenting risk.

The use of adaptive management employs risk-based approaches for managing uncertainty. For example, guidance produced by Sparling *et al*. (2015) determines pre-application survey needs for tidal and wave developments, in relation to marine mammals based on the potential impact pathways. This approach allows developers to understand likely risks and requirements based on current knowledge of impact pathways and baseline data.

4.3.2 Multiple developments (aquaculture)

Within the area of the Menai Strait there are multiple commercially active shellfish farms. The production and adoption of the CoGP by the Welsh shellfish industry (Section 4.2.3) acknowledges the proximity of shellfish farms around the Menai Strait. With adoption of the CoGP there is limited scope for a significant cumulative effect from shellfish farming as the measures outlined considerably reduce the potential for introduction and spread of INNS.

Within many sealochs in Scotland there are multiple fish farms. Understanding the extent of the potential effects from a single farm through modelling tools such as NewDEPOMOD (Section 4.2.3) will assist regulators and developers with site location for additional farms by potentially avoiding an overlap of effects at an agreed threshold.

IMTA is a form of polyculture which mimics the nutrient flows in natural systems to produce multiple outputs from a food production system. Essentially the by-products of one aquatic species provides food for another. The objective is to provide a commercially viable quantity of a selected product (i.e. fish, shellfish or seaweed) or products while reducing the environmental impact.

IMTA is being trialled in Scotland by the Scottish Salmon Company and the Loch Fyne Oyster Company in conjunction with the Scottish Association for Marine Sciences (SAMS). In the four-year trial at Loch Fyne, salmon have been farmed alongside seaweed and shellfish which maximise the uptake of organic particulates and soluble nutrients lost in the salmon feed. Successful application of this farming would allow multiple types of aquaculture to co-exist, with the cumulative effects of polyculture reducing the likelihood of a significant impact on the environment.

The Sustainable Mariculture in northern Irish sea Lough Ecosystems (SMILE) project developed carrying capacity models for five sea lough systems in Northern Ireland. These models use input data to simulate shellfish harvest and density dependent impacts, in addition to developing the ecological carrying capacity component to address environmental conservation. The model is location specific, and therefore would need calibration, through a programme of data collation and collection, to be applied in Welsh locations. However, in principle, the SMILE model has the potential to provide a method for assessing impacts of multiple aquaculture developments on key environmental variables and processes.

4.3.3 Different developments

The requirement for energy rich physical environments for both tidal and wave energy developments means that it is unlikely that new aquaculture developments would overlap in the same geographical area due to physical operational constraints on aquaculture. However, as technology develops it may eventually allow these activities to operate, and therefore occur, in the same broad location.

The specific impact pathways discussed for aquaculture (see Section 4.2.3 and Appendices F.1 to F.4) which may be affected by tidal/wave energy are limited to:

- Introduction of INNS; and
- Discharges (particulate waste, chemicals) and impacts on water and sediment quality and benthic habitats.

The presence of tidal/wave energy developments could provide a stepping-stone for the spread of INNS through the provision of a suitable attachment surface. The co-location of aquaculture with tidal/wave energy devices could therefore increase the risk from INNS

Tidal/wave energy developments will change hydrodynamics with resultant changes to sediment transport. Where such changes have the potential to affect water and sediment quality in an area utilised or proposed for aquaculture a cumulative effect may result on marine features. Understanding the potential effects through hydrodynamic and sediment transport modelling in addition to tools such as NewDEPOMOD will assist cumulative assessments.

As the specific impact pathways for wave and tidal arrays are the same, where proposals for both these activities occupy the same geographical area the consideration of cumulative effects and recommendations would be the same as that provided for multiple developments of the same activity (see above).

4.4 Concluding remarks

The recognised potential for tidal stream, wave energy and aquaculture in Welsh waters provides clear incentives for understanding the environmental impacts associated with the focus activities and, hence, the likely consenting risk to interested developers.

The recent emergence of tidal stream and wave energy technologies means there are some uncertainties on the likelihood and magnitude of environmental impacts. Although the impacts of aquaculture are better understood, with many commercial examples of shellfish aquaculture (e.g. Menai Strait, Scotland and Ireland) and finfish aquaculture (sealochs) across the UK and Ireland, it is still a developing industry. For example, some of the potential impacts from finfish farming have only recently been fully realised (e.g. genetic interaction between escapees and wild fish populations).

To understand the impacts, it has been necessary to use examples and studies from the UK, Europe and North America, as these sectors, specifically finfish mariculture, are under-developed in Wales. In many cases the generic evidence base does not provide enough confidence on the impacts with the requirement for adequate baseline data and detailed modelling is needed to understand the site-specific potential of an impact.

Rare exceptions may exist where data and studies are available which cover a particular site of interest, and thus significantly contribute to the understanding of a potential impact pathway. For example, the effects on physical processes from the tidal array at Holyhead Deep (Deep Green) were scoped out from the EIA due to various studies that had been conducted in the location of the tidal array (e.g. by SEACAMS; Potter, 2014); however, even this work was supplemented by focused geophysical and environmental surveys. Yet, this example demonstrates how the availability of quality assured data may allow enough confidence for inclusion within the baseline assessment and even the scoping out of impact pathways.

As some impacts become better understood through empirical data collection, then the evolving evidence base may allow developers to move away from predictive assessments once confidence is assured. A recent illustration was the uncertainty of evidence in relation to corkscrew injuries on seals; this was previously believed to be a result of propeller impacts. Various constraints were placed on developers to demonstrate that the proposals would not have a significant effect on seals through this impact pathway, such as the requirement for vessels not to use ducted propellers. However, field observations in the last few years have confirmed that this impact was a result of inter-species predation and this impact pathway is no longer being a consideration to marine developments.

In October 2018, Marine Scotland published the Scottish Marine Energy Research (ScotMER) evidence maps[6]. These provide summaries on knowledge gaps in relation to various marine feature groups and the potential effects of renewable developments. The ScotMER programme has identified key research priorities, some of which encompass the specific impact pathways identified in this section. These include various studies which are currently underway to inform collision risk to marine mammals form tidal turbines e.g. research to address precautionary assumption that all collisions with turbines are fatal.

[6] https://www.gov.scot/Topics/marine/marineenergy/mre/research/maps

Case examples of tidal stream and wave energy technology are generally confined to small or single demonstration devices that are short-term (less than one year). Until multiple tidal or wave devices are deployed with substantial monitoring programmes, information about underwater noise, collision, EMF and barrier impacts will continue to depend on laboratory experiments, predictive modelling and observations from individual devices.

The ScotMER programme acknowledges the considerable knowledge gaps on cumulative effects with signposting to several studies investigating the effects on physical and ecological processes from large scale wave and tidal energy developments. Remaining abreast of the ScotMER programme as findings are documented according to the latest scientific evidence will fill gaps in the evidence base.

There is minimal overlap of the focus activity draft SRAs; however, to the west of Anglesey and around St David's Head, the boundaries of SRAs for aquaculture and tidal stream activities are adjacent. As the boundaries of the other SRAs are defined, the potential implications on specific impact pathways from their cumulative effects will need consideration as will consideration of existing or planned activities.

With the uncertainties and limitations of evidence surrounding new technologies, developers should assume that adoption of a 'survey, deploy, monitor' policy will be a condition imposed within the consenting of these focus activities. Such a condition will provide continuing development of the evidence base and allow adaptive management to be implemented as a risk management measure.

Encouraging commercial bodies to make evidence and data collected publicly available will allow emerging industries to understand potential issues and prepare accordingly to ensure consenting risk is kept to a minimum and conditions are proportionate as the sectors evolve.

A range of guidance and tools are available to help developers understand the potential impacts, assessment requirements and management measures for the focus activities and wider initiatives (Appendices G and H). Despite much of the guidance and many of the tools not being specific to Welsh waters they provide a good starting point and should be signposted during initial consultation.

5 Further Considerations

This section discusses issues and considerations which are relevant to the objectives of this study, including sustainable development of the focus activities, or the broader WNMP. Some of the issues have been identified during this project (WP1) while others are highlighted as additional considerations beyond the scope of the work.

It is broken down into the following subsections with interlinkages between each:

- Data;
- Far field effects and supporting infrastructure;
- Cumulative;
- Consenting process; and
- Future proofing.

5.1 Data

Limitations to the collated data have already been identified within Section 3.7. However, as a wider point, the comparative wealth of marine environmental data at some locations should not be assumed as comprehensive for either site selection or assessment purposes. As with all developments, data will need to be site specific and encompass all relevant environmental features. Furthermore, currency and confidence in data will reduce over time. This data collation exercise represents a snapshot in time and as such there is a need for continual updates to provide maximum confidence in the evidence base.

The majority of the 'high scoring' data collated for Welsh waters (Table 12) are biological datasets. Despite the comparatively greater data availability for biological features this type of data is often very site specific. Additionally, coverage and quality of data for designated nature conservation areas is likely to be better than non-designated areas.

The provision of good biological data in a given area may assist with site selection but it should not be assumed that this would be sufficient for assessment purposes. The need for high resolution and up-to-date data will likely result in site-specific surveys to further understand the potential effects during the construction and operation phase. Modelling predictions are also likely to require post-consent monitoring studies especially where there are recognised uncertainties around an impact pathway (e.g. collision risk to birds, fish and marine mammals from tidal stream turbines).

In this context stakeholders have suggested guidance on data collection methods for different receptor types, likely data requirements and assessment techniques (e.g. modelling) would be beneficial. In addition, there is increasing recognition that a robust scoping exercise (both by developer and regulator) would reduce uncertainties.

5.2 Far field effects and supporting infrastructure

Recognising that the effects from the focus activities have the potential to be experienced beyond the localised footprint, an awareness of potential impact pathways and data availability in the far-field zone is also required. It should not always be assumed that if good quality data is available in the near field, then this would be enough to inform site selection or baseline assessment. Furthermore, far-field effects on sensitive features could be as much of a consenting risk as potential near-field effects.

Whilst the study has identified areas within and outside draft SRAs where data availability is comparatively better, careful consideration will also need to be given to necessary supporting infrastructure. In some cases, the infrastructure may already be available, for example subsea cables for renewables. However, there is likely to be some form of additional development required, particularly to support the tidal stream and wave energy sectors. Onshore infrastructure may be many kilometres from the development, hence, it is important to understand if gaps in the data exist over areas (marine and terrestrial) potentially required to support the development(s).

As a general issue the absence of any high voltage power lines and subsea cables near to tidal stream or wave energy draft SRAs is an important factor which, while outside of the remit of this work, has the potential to jeopardise commercial development, through excessive project connection costs or unacceptable consenting risks on the wider environment. Grid connection, although available to prototype renewable energy developments in Ramsey Sound (e.g. DeltaStream developed by Tidal Energy Ltd) may not be sufficient for commercial scale development. Interrogation of the Welsh Marine Planning Portal shows that the draft tidal stream SRA around St David's Head and through Ramsey Sound is not close to any submarine cables or any high voltage connections on land. Irrespective of any other factors, the requirement for extensive power line and cable infrastructure may make such an option unattractive to developers, owing to the potentially high costs of connecting to the electricity grid.

5.3 Cumulative

Provided sufficient resource is available for the focus activity, the inshore environment will be more attractive to developers; however, inshore areas generally have a greater number of users, consequently developments close inshore are more likely to result in significant cumulative effects during the construction and operational phases.

Data availability and quality will generally be greater inshore. So, from a data perspective alone the inshore environment may initially appear more attractive for development. However, this needs to be balanced against existing pressures and new or increased pressure from the focus activity.

A key consenting risk to developers is the potential overlap with designated conservation sites (e.g. Natura 2000) and areas containing benthic features of high value (e.g. Section 7 habitats). As marine conservation areas cover most of Welsh territorial waters, overlap with these areas is inevitable. Mapping the constraints and opportunities by incorporating relative risk will allow rationalisation of the SRAs at a high level. Where focus activities (or other SRA activities) overlap with sensitive features then adaptive management will provide an iterative process to reduce impacts.

In some cases, it is already clear where considerable constraints on focus activity development within draft SRAs would occur. For example, draft SRAs for aquaculture and tidal stream encompass Ramsey Sound. However, this area has multiple conservation designations (e.g. Pembrokeshire Marine SAC, West Wales cSAC, Ramsey Island NNR, Ramsey SSSI and Pembrokeshire Coast National Park). There are seal pupping haul-out sites in the area and it is a busy route for recreational boat users. St David's Head and Ramsey Island are also a Registered Landscape with seascape views an important feature.

Even without consideration of all available data, the constraints on potential commercial development within and around Ramsey Sound are clearly demonstrated.

5.4 Consenting process

Lack of consistent guidance in relation to the focus activities can lead to adoption of a precautionary approach to consenting rather than one that is proportionate. Advice or opinions received from regulatory authorities can sometimes be contradictory and inconsistent with a reliance on previous projects which might not be relevant or proportionate (e.g. offshore wind, oil and gas infrastructure).

Greater clarity on the decision-making process should be provided within guidance so the process is transparent and consistent. Stakeholders have continually identified the speed of consenting decisions as a significant hurdle to development; for example, stakeholders at a shellfish aquaculture workshop in December 2018 (Bangor Shellfish Centre) highlighted the speed of consenting as the priority constraint to growth of the shellfish industry.

Post-consent monitoring is often a condition of the consent and is almost an assumed requirement within emerging technologies in the context of 'survey, deploy, monitor' policies. However, the effectiveness of monitoring to validate the assessments or inform future work is not clear, with the design of monitoring programmes a balance between meeting the condition of the consent and providing data that in some way aligns with the objectives. Within the draft WNMP (Welsh Government, 2018) it states that 'requirements to undertake post-consent monitoring and reporting should be proportionate and clearly related to the key potential issues identified during authorisation of a proposal. However, monitoring should not be made a condition of consent where the sole purpose is to further the sector.' Stakeholders have questioned the effectiveness of post-consent monitoring and the value of collecting data where there are limited mechanisms for any feed back into the assessment process.

Ultimately the selection of SRAs should give some confidence to developers that the relevant focus activity will not have major obstacles with the consenting process. It has already been acknowledged that many of the draft SRAs overlap with Natura 2000 sites, in addition to co-existing with a wide range of other marine users. Knowing that these consenting issue considerations have been recognised in the SRA selection should provide a level of assurance to developers. However, the SRAs do not create a presumption in favour of development and all projects will need to be tested through EIA and HRA processes to determine their acceptability and requirements for mitigation and offsetting measures.

Understanding the current utilisation of a selected area by other users along with the presence of environmentally sensitive features, will allow a high-level appraisal of an area's suitability before further steps are taken.

5.5 Future proofing of SRAs

At a general level, public opinion may be more accepting of wet renewables than aquaculture, especially since tidal stream turbines may have low visibility once operation commences. It is the general expectation that future aquaculture developments will be able to move further offshore as the technology advances, allowing cost-effective production while reducing the pressures on the inshore environment. If the Welsh aquaculture sector does not grow and move offshore, then there is no value to identifying many of the offshore aquaculture SRAs.

Whilst technology may allow aquaculture to take place offshore, the constraints placed by the prevailing physical conditions will be key to site selection. Hence, areas exposed to south westerly winds and waves are unlikely to be considered unless there are no other feasible options. Where the resource is suitable, there will be a preference for locating within estuaries, bays and inlets. After which, areas that are afforded protection by the land to prevailing conditions would be considered next. While the draft SRAs for aquaculture may be in locations of suitable resource, there are many areas that are likely to be too exposed for any commercial development in the near future. The Menai Offshore Subsurface Shellfish Systems (MOSSS) is currently being funded through the EMFF to support the piloting of commercial-scale offshore shellfish production systems, using a test site to the east of Puffin Island and the investigation of suitable environmental conditions for their potential deployment in Welsh waters. However, this test site is considerably more sheltered than some of the draft SRAs allocated for aquaculture.

Although still evolving, shellfish aquaculture has been part of Welsh heritage for many decades. The WNMP is about enabling sustainable blue growth (see Section 1). For growth to occur the existing industry has to be maintained. Existing Welsh shellfish aquaculture is predominantly located within and around the Menai Strait. The strong flows and sheltered environment providing ideal conditions for mussel farming. Many of the operational farms overlap with the Menai Strait and Conwy Bay SAC (designated for subtidal sandbanks, intertidal mudflats and sandflats, and reefs) but predate the EC Habitats Directive by several decades.

Ideally, new developments would be located outside of designated conservation areas if there is potential for a given development to have negative impacts on interest features. Such a strategy would likely reduce consenting risk, pre-application survey work and monitoring requirements. However, where activities, such as shellfish aquaculture existed within an area before designation, then they should be acknowledged as part of the baseline features of a site. It is likely that many of the inshore areas currently utilised for aquaculture represent the optimum locations and are therefore the most profitable. Reduction or loss of output in these key locations would slow growth of the industry as it waits for technology to provide a cost-effective option offshore.

6 Key Recommendations

This section provides key recommendations that have resulted from this study. It is divided into the following subsections:

- Data – key gaps and recommendations;
- Evidence – modelling, post-consent monitoring and feedback;
- SRAs – constraints and high-level recommendations for refining SRAs;
- General – consenting, guidance and tools; and
- Future work – desk studies, surveys and case examples.

6.1 Data

During the data collation and consequent analyses, gaps were identified resulting in recommendations for site selection and particularly baseline characterisation (Section 3.6). The main gaps in spatial coverage of high scoring data encompassed the following:

- Physical data restricted beyond the inshore environment with less data available in southwest territorial and offshore waters – gap for wave energy SRA and general data limitations for tidal stream/wave energy across Welsh waters;
- Chemical data close inshore – chemical data generally restricted to inshore and transitional water bodies. Water chemistry important for aquaculture;
- Biological data limited as move offshore - comparatively few datasets for offshore wave energy SRA and tidal stream SRAs west of Anglesey and in the Bristol Channel; and
- Human environment – fisheries and tourism/recreation data gaps. Limited spatial coverage of human environment layers to the west of Anglesey and south west Welsh waters.

Although large data gaps exist for physical and chemical data, especially offshore, these data are sufficient to inform initial site selection and feasibility considerations and are not carried through to the recommendations for tidal stream and wave energy. However, they are important for inshore aquaculture and are acknowledged below.

To aid site selection and high-level baseline characterisation, the following are key recommendations for data that would be a useful addition to data collated to inform this project, and provide characterisation of Welsh waters that could be useful to developers and regulators, as well as marine spatial planning more widely:

- Data (physical, chemical and biological) from WFD Cycle 2 – this data exists and could aid inshore aquaculture development;
- Further information on benthic habitat (including Section 7 habitats) condition and extent – will inform site selection and baseline characterisation for all sectors;
- Basking shark distribution dataset – this will inform tidal stream and, to a lesser extent, wave energy sectors;
- Marine non-native species 'hot-spot' data – EMFF funded project refining maps for Wales will inform all sectors, particularly aquaculture.
- An up-to-date marine mammal distribution dataset – will inform all sectors and impact pathways such as collision risk and barrier effects;
- Wading bird distribution – inform aquaculture site selection;
- Diving seabird distribution – inform all sectors; and

- Inshore fisheries data – updated fisheries data will help inform site selection and baseline for all sectors recognising the limited spatial data on inshore fishing vessels (<12 m).

Some of the recommendations for biological data may be informed, at least in part, through desk study and data sharing (e.g. shark distribution; inshore fisheries); however, it is assumed that targeted survey programmes are likely to be required to inform data gaps on seabirds, marine mammals and benthic habitats. This is discussed in more detail under future survey work (Section 6.5).

Seabird distribution shows a high degree of temporal variation and even though existing data may supplement baseline surveys it is assumed that baseline characterisation would still require either 1 or 2 years' worth of seabird surveys, depending on the availability and age of existing data. Although the RSPB have colony specific tracking data through projects such as FAME and STAR (Section 3.6.3 and 3.6.4) this does not provide the necessary spatial distribution and intensity data. A broadscale study is recommended for the whole of Welsh waters using aerial survey to obtain an overall picture of key functional areas. The aerial survey could also be used to collect better marine mammal (cetacean and seal) distribution data. Such broadscale data will be important in supporting marine spatial planning, particularly in identifying hotspots to be avoided as well as providing contextual information for project level developments.

Refining the seabird data to produce a diving seabird layer would be particularly useful for collision risk modelling although additional location specific survey data will likely be required.

To assist future development of the focus activities all 'recommended' datasets (Table 11) should be available from a single source e.g. the Lle Geo-Portal (linked to the Welsh Marine Planning Portal) (see ABPmer, 2018b). As they become available, these datasets should be uploaded to the portal and quality assured according to a consistent and repeatable approach that is transparent to future users.

The portal should be regularly updated and reviewed to maintain confidence in data provided; for example, highlighting the age of datasets. Signposting to data sources which are either not accessible or not available as metadata is also recommended.

6.2 Exposure and sensitivity to specific impact pathways

Uncertainties in relation to exposure and sensitivity of a feature (Section 4) can lead to a reliance on modelling predictions and the extensive requirements for post-consent monitoring. Modelling that is currently used to assess collision risk and barrier effects is derived from distribution and density data of a mobile feature.

To increase the evidence base, key recommendations are:

- Ensuring empirical studies and post-consent monitoring are carried out;
- Guiding post-consent monitoring work so it is proportionate whilst based on sound science. this could be achieved through public funding of post-consent monitoring work to maximise learning from early arrays;
- Mechanisms to ensure monitoring outputs feedback to benefit future developments, modelling and assessment approach;
- Using risk-based approaches to manage uncertainty including adaptive management to facilitate proportionate decision making; and
- Maintaining awareness of and involvement in key fora such as ORJIP and other co-ordinated research programmes.

6.3 Strategic Resource Areas

Provision of the data recommended above (Section 6.1) will begin to allow SRAs to be rationalised and boundaries to be refined. Much of the biological data will require broadscale surveys to collect new data and validate existing records. This should specifically include Section 7 habitats. A search feature list derived from the Section 7 habitats is recommended to inform broadscale survey work.

Based on the data already available and acknowledging the likely constraints, some high-level observations can be made on several draft SRAs for the focus activities (see below). As a first step, rationalising the SRAs based on existing knowledge will ensure that data collection efforts are concentrated on the most viable SRAs for a given activity. This could be done through risk matrices and mapping constraints and opportunities. However, it is recognised that the next phase (WP2) will provide supporting evidence for refining the boundaries of focus activity SRAs

6.3.1 Environmental constraints within draft SRAs

Sections 5.2 and 5.3 have already highlighted the challenges with promoting development of the draft SRAs (tidal stream and aquaculture) within and around Ramsey Sound based on the multiple overlaps with designated conservation areas, the multiple users of the area and the likely requirement for an extensive power line and cable infrastructure to support the development of any commercial tidal stream operation. The sound is also an unusual feature in its own right, there being only two other sounds in Welsh waters.

The tidal stream draft SRA located off the north coast of Anglesey is wholly within the North Anglesey Marine SAC and Anglesey Terns SPA, respectively designated for harbour porpoise and terns. Harbour porpoise and bottlenose dolphins are commonly recorded along this stretch of coastline and there are is also a seal haul-out area at the Skerries. At the time of writing, a Development Consent Order application for the proposed Wylfa Newydd Nuclear Power Station is going through the examination phase. Should the application be recommended there would be an extensive construction phase, encompassing dredging and marine disposal, harbour infrastructure and a large breakwater. During the operation phase of the power station the dispersal and dilution of the thermal discharge is reliant on the strong tidal flows. Proposals for commercial tidal arrays would therefore need to consider the potential for cumulative effects with the power station during construction and operation. The potential effects of the thermal plume would also need to be considered for aquaculture; at the moment there are draft aquaculture SRAs in Cemaes Bay, to the east of Wylfa Head.

6.4 General recommendations

Within the study consideration has been given to the consenting process as well as guidance and tools relevant to the focus activities (Appendices G and H).

Key recommendations in relation to consenting are:

- Greater clarity on the relationship between SRAs and project level decision making process; and
- Ensuring that the scientific evidence available for impact pathways associated with the focus activities, provides suitable confidence in the assessment and suggested mitigation measures.

Key recommendations in relation to guidance are:

- Structured guidance specific to tidal stream, wave energy and aquaculture developments in Welsh waters should be developed; and
- Providing an online toolbox covering consenting *and* assessment guidance related to each of the focus activities; including likely data requirements (collection methods) and assessment tools e.g. models.

Key recommendations in relation to tools are:

- Providing links to online assessment tools endorsed by Welsh regulators; or
- Developing publicly available online assessment tools specific for the focus activities in Welsh waters.

The benefits from these recommendations would be that the development requirements (e.g. consenting, assessment, monitoring) would be consistent and understood by all stakeholders.

6.5 Future work

The final section provides key recommendations for future work and gives three case examples of potential options to provide data that would benefit the three focus activities.

6.5.1 Targeted studies

This study has identified a number of data gaps which can be filled through targeted work programmes. As an initial step it is recommended that constraints and opportunities mapping is carried out to refine focus activity SRAs and define boundaries. This work will then inform search areas (in and around SRAs) for broadscale survey work and desk studies.

It is recommended that broadscale benthic habitat surveys are carried out to inform presence, condition and extent of sensitive features within targeted SRA locations. Recognition should be given to Section 7 and Annex I habitats. Understanding the presence of these features will allow development of benthic maps which will further refine SRA boundaries and guide location of SRA activities.

It is recommended that both marine mammal and seabird surveys are carried out as part of a combined aerial survey covering the entirety of Welsh waters. This will need to be multiyear and take account of the location of fronts and their variability between years to identify key foraging areas.

6.5.2 Case examples

A series of example Case Studies have been provided, to illustrate the processes and options to fill data gaps for a range of purposes. It should be noted that, whilst the following examples are based on previous project experience of data collection, they are largely hypothetical and are intended for illustrative purposes only.

The following sections provide examples of data collection:

- To refine a draft SRA boundary;
- To fill an identified data gap; and
- To inform development of the proposed META test site.

Case Study 1: To refine a draft SRA boundary

The boundaries of draft SRA's have often been defined at a high-level and could be refined through further data review and analysis.

A generic overview of the process that could be used to refine the extent of a draft SRA is provided (Table 13).

Table 13. Process to refine the extent of a draft SRA

<table>
<tr><th></th><th colspan="2">Description</th></tr>
<tr><td>Purpose:</td><td colspan="2">To refine a draft SRA boundary</td></tr>
<tr><td></td><td colspan="2">Where data gaps exist, potential benefit could be gained from collecting new datasets, in and around the defined draft SRA's. Focusing on these areas when looking to fill data gaps will likely enable subsequent refinement to the SRA boundaries, and help inform subsequent site selection activities.</td></tr>
<tr><td>Context:</td><td colspan="2">Provide a more focussed boundary for project development</td></tr>
<tr><td></td><td colspan="2">A more focussed SRA boundary will help inform site selection for development of individual projects and help constrain the study area for any additional data collection activities, as required.</td></tr>
<tr><td colspan="3">Step 1: Identify key data types</td></tr>
<tr><td></td><td colspan="2">Dependent on the industry sector focus of the SRA (Aquaculture, Tidal Stream etc.), different types of data will be more relevant than others.
Once the key data types have been identified, datasets that fall into these categories can be assessed.
Taking the Tidal Stream SRA as an example, and focussing on the 'baseline and assessment' project stage:</td></tr>
<tr><td>Key data types:</td><td colspan="2">Tidal Stream SRA (from types identified in Table 11):
▪ Bathymetry; Tides/Waves;
▪ Protected habitats and species;
▪ Distribution of fish, mammals and birds;
▪ Marine aggregates; Ports and shipping; Fisheries; Defence; and
▪ Protected area boundaries</td></tr>
<tr><td colspan="3">Step 2: Identify key data layers</td></tr>
<tr><td></td><td colspan="2">Key datasets that have already been collated can be assessed (as identified in Step 1) to see if (and how) they might add additional information to a draft SRA. Similarly, identified data gaps can also be prioritised to determine which data gaps are most beneficial to fill (based on perceived value vs. likely cost).
Taking the Tidal Stream SRA as an example, and considering the datasets collated for the present Welsh Government study:</td></tr>
<tr><td>Key data layers:</td><td>Tidal Stream SRA example
▪ EMODnet_DEM_clip
▪ EMODnet_Current Energy
▪ Renewables_Atlas_Tide
▪ TCE_Minerals_Aggregates</td><td>(Selected data layers)
▪ Designated site boundaries
▪ Fish, mammal and bird data
▪ MMO_UK_Fishing_Activity
▪ AIS_Transit_Lines</td></tr>
<tr><td colspan="3">Step 3: Establish criteria to enable prioritisation of gap filling</td></tr>
<tr><td></td><td colspan="2">A clear set of criteria can be defined, in order for budgets to be spent in the most efficient way, collecting valuable data, with the aim of refining the existing draft SRA boundaries and helping focus subsequent site selection activities.</td></tr>
</table>

	Description
	For example, the prioritisation criteria could include consideration of: ▪ Target data-type for collection; ▪ Scale and intensity of survey (relative to available budgets); ▪ Likelihood of timely data collection (taking account of likely weather downtime etc); ▪ How data collection will fill an identified data gap; ▪ Level of developer interest in a given SRA (and overarching project timelines); ▪ Potential for multiple benefits from a single data collection campaign (can a study be undertaken that fills multiple data gaps, or that supports multiple activities); and ▪ Overall value for money of the activity.
Step 4: Data collection	
	Based on the above defined criteria, the target data type(s) and the available budget, a campaign of modelling and/or survey data collection can be scoped, tendered and undertaken (i.e. collection of benthic habitats and species data over an identified survey area).
Step 5: Assess influence of constraints and opportunities on SRA	
	Key data layers should be mapped, with overlap and proximity to the draft SRA noted. The influence of each identified data layer on the SRA can then be considered to determine whether the data supports use of the SRA for the defined purpose or whether a constraint to Project development exists. Areas which support Project development can then be refined, and areas where constraints exist can be highlighted as such or excluded from the SRA altogether (where the constraints are such that they preclude a given area from development).
Step 6: Refine SRA boundaries	
	Taking the above defined constraints and opportunities into account, the draft SRA boundaries can be refined, based on the assessment of available data.
Timescale:	When considering only the data already available (and collated for the present study), the SRA's of interest (Aquaculture and Tide/Wave Energy) could be assessed, and boundaries refined within a period of around 6 - 8 weeks.
Cost:	When considering only the data already available (and collated for the present study), the cost of refining the SRA's of interest would likely be in the region of £5,000 to £10,000. If additional SRA's and/or additional data collation is required, timescales and costs would increase on a *pro-rata* basis.

Case Study 2: To fill an identified data gap

A generic overview of the range of options available to fill an identified data gap is provided (Table 14).

Table 14. Options to fill an identified data gap

	Description
Purpose:	To fill an identified data gap
	Data gaps may be identified by data type and/or by geographic location. For example, data related to 'wave' conditions may be generally sparse or may be limited over a specific area of interest. A range of options for filling such identified gaps are available; the most appropriate method(s) are likely to be influenced by the nature of the data gap and the requirements of the subsequent infill data.
Context:	For generally sparse data types
	Where the study has identified a general data gap over the wider study area, such a gap could be filled using the following methods (in order of ease of collecting).
i. Existing third-party data	
	It is possible that data to fill the identified gap has already been collected (or created) by a third party or held and made available under licence for use by others (or that which has been collected/ made available since this project completed). This type of data could include: ▪ Survey data collected for a different project/study; ▪ Numerical model data from regional/far-field models
Pros:	This is likely to be the quickest and easiest way of filling an identified gap. Since the data has already been collected, processed and (in all likelihood) reported on, the requirement for bespoke survey operations or numerical modelling is not necessary.
Cons:	Data type, format, coverage and quality is already predetermined by the holder/creator of the data and may not necessarily be exactly aligned to the ideal gap fill requirements. In addition, depending on the amount of metadata available, subsequent scoring (to determine usefulness) of third party data may be difficult.
Timescale to fill:	Likely to be a matter of days, dependent on data format, delivery method and negotiation on licence fee (where applicable).
Cost to fill:	Dependent on licence fee (where applicable), but substantially less than developing a bespoke dataset.
ii. Bespoke numerical modelling data	
	Where pre-existing infill data is not available, numerical modelling can provide predicted data over a wide area of coverage, and for a range of parameters. Typically, this could include output for: ▪ Hydrodynamics (tides and flows); ▪ Waves; ▪ Sediment transport; ▪ Water quality; and ▪ Ecological predictive models etc.
Pros:	Likely to provide coverage of infill data over a large area, and model(s) can be designed with the specific data requirements in mind. Often bespoke models

	Description
	can be driven by boundary conditions extracted form pre-existing global-type models, saving time and cost. Model performance can be assessed quantitatively against calibration data, where available, adding confidence to the outputs.
Cons:	Numerical modelling inherently uses a range of assumptions with its inputs to replicate real-world conditions. Confidence in model outputs requires verification against measured data, which may not be available over a wide area (hence the initially identified data gap). With added levels of complexity, numerical models can be timely (and, hence, relatively costly).
Timescale to fill:	Weeks to months, dependent on the spatial and temporal requirements. Model dependencies might mean extended time periods (e.g. where wave-current interaction is important, wave modelling is dependent on tide and flow input data (or a sufficiently well-performing hydrodynamic model)).
Cost to fill:	Dependent on coverage requirements and parameters, typically £10-20,000 for a bespoke, high-level, calibrated hydrodynamic model, using available input data (existing models, regional bathymetry data, suitable boundary condition, etc.).
iii. Bespoke survey campaign	
	If necessary, the data gap(s) could be filled through collection of additional data through a bespoke survey campaign. This type of data could include: ▪ Metocean data (tides, waves, winds etc.); ▪ Geophysical/geotechnical data (bathymetry, sedimentology, sub-surface geology etc.); ▪ Water/sediment quality (chemical analysis, contaminants, nutrient loads, river flow etc.); ▪ Ecological data (fish counts, marine mammal observations, plankton survey, habitat mapping etc.); and ▪ Human activity (shipping, fishing, recreation etc.).
Pros:	In effect, a gap for any data type can be filled through a targeted survey campaign, including data types that can't be modelled. The 'survey' could take a number of forms, including deployment of instrumentation; collection and analysis of sample data; questionnaires/online surveys sent to local interest groups etc. The survey(s) can be focussed on the specific needs of the infill data.
Cons:	Survey data can have limited coverage, particularly where instrumentation is deployed, or samples collected. More deployments and more samples can be used to extend the coverage, but this comes with an overhead of time and cost. Where the data collection involves offshore deployments, weather downtime can result in delays (and added cost).
Timescale to fill:	Likely to be in the order of months, particularly where deployment/sample collection is involved and post-processing and/or analysis is required. Where responses are requested from third parties (e.g. local interest groups), there is no guarantee of the level (and speed) of engagement, or of the number of responses.
Cost to fill:	Can range from relatively inexpensive online survey forms, targeted at specific stakeholders; to costly and complex metocean deployment and sampling/analysis campaigns. Typical costs can rise to at least £50,000 to £100,000, particularly with offshore activity (with specific vessel/crew requirements), multiple deployment locations, weather downtime etc.

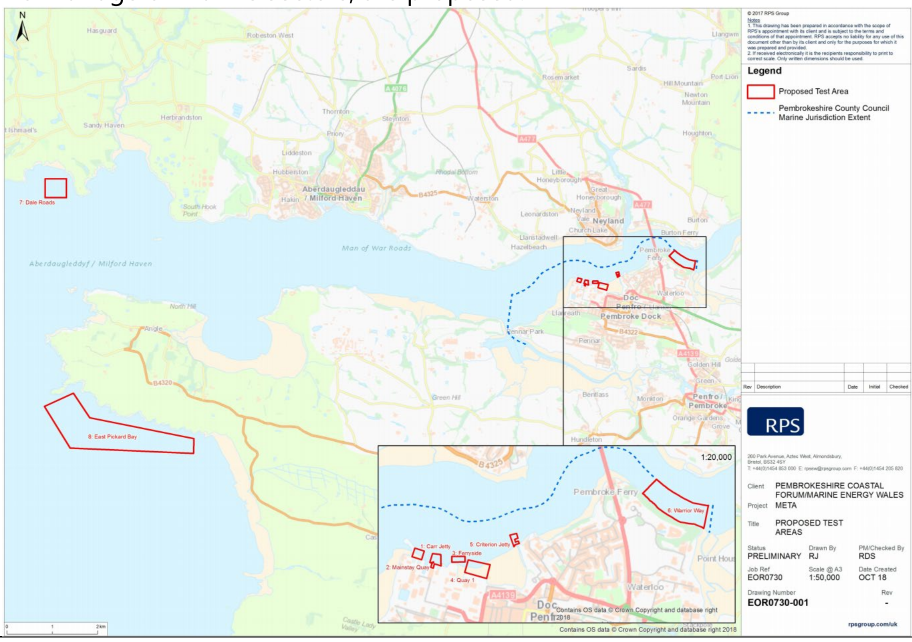
Case Study 3: To inform a META-test site

Marine Energy Wales is developing a Marine Energy Test Area (META) project in and around the Milford Haven Waterway. Sites for testing wave and tidal devices, along with other marine energy equipment, are proposed near Pembroke Port, Warrior Way, Dale and north of Freshwater West.

It is intended that META will provide a stepping stone between tank testing and installing devices further offshore and will support ambitions for the UK to continue to play a global leading role in marine renewable energy.

This test site has been selected as a Case Study to illustrate the potential benefits that could be gained from data collection for multiple purposes, since deployments for all three activities of interest could be placed in close proximity to each other (Table 15).

Table 15. Options to further inform development of a META-test site

	Description
Purpose:	To further inform development of a META-test site
	As part of the META project, a series of 8 test deployment sites have been proposed in and around the Milford Haven waterway region. The aim is to provide a test bed for interim deployment of marine energy devices, and other marine infrastructure (including aquaculture related equipment). As a result of the proposed multi-purpose deployment sites, a campaign for additional data collection could be developed to further inform Projects from a range of sectors.
Context:	Multi-purpose data collection
	Within the META test area (and, more widely, where SRA's and subsequent potential Projects exist in close proximity to each other), multi-purpose data-collection campaigns could be developed, to provide data requirements across multiple sectors (with benefits gained from economies of scale). The image below provides a summary of the draft test deployment sites from the META project, covering an area approximately between Pembroke Dock and St. Annes Head. Within these regions, test deployments of equipment, from a rage of marine sectors, are proposed. 

	Description
Identify opportunities to fill multiple data gaps	
	Where data gaps have been identified across multiple sectors and/or Project phases, data collection can be focussed with resultant benefits across a range of sectors and/or Project developments. The process for data collection to fill data gaps should generally follow that defined in Case Study 1, whereby key data types are listed and referenced against identified gaps. Then a set of criteria can be utilised to make best use of available budgets, maximising the opportunity to collect data with a high value to associated sectors. Given the proximity of different sectors within the META test site region, a single data collection campaign (which could be survey or modelling or a combination of both) could benefit tidal stream energy, wave energy and aquaculture test sites.
Pros:	Close proximity of a range of sectors provide opportunity to increase value of any data collection with multiple benefits to development of technology across a number of Project types. For example, there exists extensive biological and water quality data for the area around Cleddau Bridge, down to Pennar Gut. This data has been collected for over 5 years to inform effects from the Pembroke CCGT Power Station, in operation since 2012 (and includes fish surveys, water quality surveys, benthic data). NRW holds this data, although it is commercially sensitive and, hence, not publicly available.
Cons:	Survey data can have limited coverage, particularly where instrumentation is deployed, or samples collected. More deployments and more samples can be used to extend the coverage, but this comes with an overhead of time and cost.
Timescale:	Likely to be in the order of months, particularly where deployment/sample collection is involved and post-processing and/or analysis is required. A high-level modelling study could be completed quicker (around 4-6 weeks, dependent on availability of existing models and/or data).
Cost:	Small-scale data collection (over a limited spatial extent, given the defined META test sites), would be relatively cheaper than large-scale offshore survey deployments. Typical cost could range from £10,000 - £50,000, dependent on data type and extent of coverage. A high-level modelling study, utilising existing models and/or data would likely cost in the region of £10,000 - £20,000 –dependent again on extent and scope (hydrodynamics, waves, sediment processes etc.).

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8 Abbreviations/Acronyms

AA	Appropriate Assessment
ABP	Associated British Ports
AC	Alternating Current
ACIG	Aquaculture Common Issues Group
ADCP	Acoustic Doppler Current Profiler
ADD	Acoustic Deterrent Device
AfL	Agreement for lease
AIS	Automatic Identification System
AONB	Area of Outstanding Natural Beauty
APB	Aquaculture Production Business
ARCH	Aquaculture Research Collaborative Hub
ARIES	Artificial Intelligence for Ecosystem Services
BIM	Bord Iascaigh Mhara
BOEM	Bureau of Ocean Energy Management
BTO	British Trust for Ornithology
CA	California
CAMS	Coastal and Marine Sectors
CCW	Countryside Council for Wales
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
CoGP	Code of Good Practice
CRAFT	Cooperative Research Action for Technology
CSAR	Centre for Sustainable Aquatic Research
CSEMP	Clean Seas Evidence Monitoring Program
DGU	Deep Green Utility
DHI	Danish Hydraulic Institute
DIDSON	Dual-Frequency Identification Sonar
DNMS	Drifting Noise Measurement System
DNS	Developments of national Significance
DST	Decision Support Tool
EC	European Commission
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EMF	Electromagnetic Fields
EMFF	European Maritime and Fisheries Fund
ESRI	Environmental Systems Research Institute
EU	European Union
EUNIS	European Nature Information System
FAME	Future of the Atlantic Marine Environment
FHI	Fish Health Inspectorate
FLOWBEC	Flow and Benthic Ecology
GB	Great Britain
GES	Good Environmental Status
GIS	Geographic Information System
GN	Guidance Note
GW	Gigawatts
HABs	Harmful Algal Blooms
HABMAP	Habitat Mapping for Conservation and Management of the Southern Irish Sea

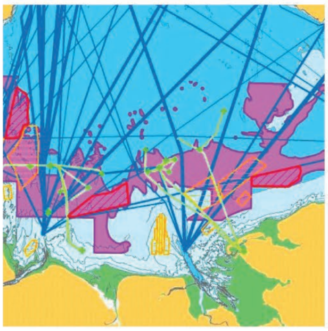
HM	Her Majesty's
HRA	Habitat Regulation Assessment
HLMOs	High Level Marine Objectives
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
ICES	International Council for the Exploration of the Seas
IMP	Integrated Maritime Policy
iMarDis	Integrated Marine Data and Information System
IMTA	Integrated Multi-Trophic Aquaculture
INNS	Invasive Non-Native Species
INSPIRE	Infrastructure for Spatial Information in Europe
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
JNCC	Joint Nature Conservation Committee
KHPS	Kinetic Hydropower System
KW	Kilowatt
LUC	Land Use Consultants
MCAA	Marine and Coastal Access Act
MCS	Marine Conservation Society
MCZ	Marine Conservation Zone
MEDIN	Marine Environmental Data and Information Network
MEECE	Marine Energy Engineering Centre of Excellence
MERP	Marine Ecosystems Research Programme
MESH	Mapping European Seabed Habitats
META	Marine Energy Test Area
MIMES	Multiscale Integrated Models of Ecosystem Services
MMO	Marine Management Organisation
MNR	Marine Nature Reserve
MOSSS	Menai Offshore Subsurface Shellfish Systems
MPA	Marine Protected Area
MPS	Marine Policy Statement
MR	Marine Recorder
MSC	Marine Stewardship Council
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
MTAN	Minerals Technical Advice Note
MW	Megawatt
NBN	National Biodiversity Network
NNR	National Nature Reserve
NRW	Natural Resources Wales
NSIP	Nationally Significant Infrastructure Project
NW	North Wales
OGN	Operational Guidance Note
ORE	Offshore Renewable Energy
ORJIP	Offshore Wind, Offshore Renewable Joint Industry Project
OSGB	Ordnance Survey of Great Britain
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAM	Passive Acoustic Monitoring
PINS	Planning Inspectorate
POL	Proudman Oceanographic Laboratory
PMSS	Project management Support Services
PNNL	Pacific Northwest National Laboratory
PUD	Public Utility District

QA	Quality Assurance
QMS	Quality Management System
RITE	Roosevelt Island Tidal Energy
RSPB	Royal Society for the Protection of Birds
RYA	Royal Yachting Association
SAC	Special Area of Conservation
SAMS	Scottish Association of Marine Science
SARF	Scottish Aquaculture Research Forum
SBT	Split Beam Transducer
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
ScotMER	Scottish Marine Energy Research
SEACAMS	Sustainable Expansion of the Applied Coastal and Marine Sectors
SEAFISH	Sea Fish Industry Authority
SEA	Strategic Environmental Assessments
SEPA	Scottish Environment Protection Agency
SHA	Statutory Harbour Authority
SMILE	Sustainable Mariculture in northern Irish sea Lough Ecosystems
SMMNR	Sustainable management of Marine Natural Resources
SMRU	Sea Mammal Research Unit
SNH	Scottish Natural Heritage
SONAR	Sound Navigation and Ranging
SPA	Special Protection Area
SRA	Strategic Resource Area
SSSI	Site of Special Scientific Interest
SST	Sea Surface Temperature
STAR	Seabird Tracking and Research
TAN	Technical Advice Notes
TBG	Transition Bro Gwaun
TEC	Tidal Energy Converters
TCE	The Crown Estate
TSS	Turbine Support Structure
TTG	Tidal Turbine generator
UK	United Kingdom
UKDMOS	United Kingdom Directory of Marine Observing Systems
USA	United States of America
UTM	Universal Transverse Mercator
VMS	Vessel Monitoring Systems
WeBS	Wetland Bird Survey
WFD	Water Framework Directive
WG	Welsh Government
WGS	World Geodetic System
WMPP	Welsh Marine Planning Portal
WNMP	Welsh National Marine Plan
WP	Work Package

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices



Innovative Thinking - Sustainable Solutions

A Stakeholder Engagement Events

Event	Programme	Objective
Progress reporting	Monthly	Monitor project progress and risks.
Inception meeting	24 January 2018	Agree approach to project.
Interim review meetings with Welsh Government/NRW	Quarterly (next meeting scheduled for May 2018)	Monitor project progress and risks. Ongoing input to shape project deliverables. Discuss project with NRW staff members that were unable to attend workshop 1.
SAG meeting	15 February 2018	Agree project definition and approach to workshop.
SAG meeting	22 February 2018	Agree project definition and approach to workshop.
Oceanology International Aquaculture seminars	13 March 2018	Collaborations, regulations and research as aquaculture moves into harsher environments.
Aquaculture Common Issues Group	18 April 2018	Current aspirations, limiting factors and opportunities for UK aquaculture.
Marine Energy Wales conference	19 April 2018	Current aspirations, limiting factors and opportunities for Welsh renewables.
Workshop	20 April 2018	Identification of stakeholder requirements.
Project team discussion	18 May 2018	Discussion over geodatabase format.
SAGB Annual Conference	1-2 May 2018	Shellfish opportunities in the retail sector and health food markets, post-Brexit and shellfish trade; sustainable bivalve cultivation
Progress meeting (Bangor)	23 May 2018	Progress update.
Technical discussions – NRW benthic habitats and species	23 May 2018	Inform database development and evidence gaps.
Technical discussions – NRW marine mammals	29 May 2018	Inform database development and evidence gaps.
Shellfish Association Great Britain annual forum	May 2018	Further input from key stakeholders.
Marine Energy Wales presentation	28 June 2018	Present details of this project and seek further input from key stakeholders.
Technical discussions – NRW birds	26 July 2018	Inform database development and evidence gaps.
Progress meeting	14 August 2018	Progress update.

Event	Programme	Objective
Project team discussion	23 August 2018	Database development discussion
WMAAG Meeting	26 September 2018	Disseminate aims of project and results to date.
Progress meeting	26 September 2018	Progress update.
Technical discussions – NRW fish	01 November 2018	Inform database development and evidence gaps.
Progress meeting	w/c 17 December 2018	Progress update.
Discussion with Welsh Government policy leads	TBC	Understanding of policy context and sharing of issues and how they can be best addressed.
Dissemination events	January 2019	Workshop/meeting to share outputs and shape final deliverables as well as recommendations for further work (WP2).

B Attendance at Cardiff Stakeholder Workshop

Organisation
ABPmer
Bombora wave power
Marine Conservation Society / Wales Environment Link
Marine Energy Wales
Natural Resources Wales
Port of Mostyn
RSPB
SEACAMS
Simply Blue Aquaculture
The Crown Estate
Tidal Lagoon Power
Welsh Government
WWF Cymru

C Data Requests

Organisational data request log with actions and responses.

Organisation	Action/ Response
Aquafish Solutions Ltd.	No data to share
Bangor mussel producers/ Deep Dock	*No Response*
Bangor University	Signposted relevant literature
Birdlife International	Signposted to RSPB
BlueFish	*No Response*
Bombora wave power	No data to share
CAMS (Bangor University)	*No Response*
Cefas	Website links provided to data and two spreadsheets provided 'Cefas Aquaculture'
Ceredigion County Council / WLGA	*No Response*
ECOSTRUCTURE	*No Response*
JNCC	No data to share
Marine Conservation Society	No data provided
Marine Energy Wales	Data provided 'Welsh Offshore Energy Research Database – Marine Energy Wales'
Marine Power Systems	*No Response*
MCS	*No Response*
Menai Strait Fishery Order Management Association	*No Response*
MERP	*No Response*
Minesto	*No Response*
MMO	Link to data catalogue supplied and data downloaded
Morlais Marine Energy (Menter Môn)	*No Response*
National Trust	*No Response*
Natural England	Directed to NE Open Portal.
Nova Innovation/ Green Seas	*No Response*
NW Tidal Energy	No data to contribute as project still in the development phase. Currently using SEACAMS data to model outputs. The plan is to develop a tidal lagoon between Prestatyn and Llandudno (31km long, 150km^2 enclosed sea area) with potential to generate ten times more energy than Swansea Tidal Lagoon project. Intend to submit EIA in 2019. Estimated duration of construction is five years. Added benefit of coastal protection in area which suffers from high levels of coastal erosion.
Openhydro	*No Response*
ORJIP	*No Response*
Pembrokeshire Coastal Forum	*No Response*
Port of Milford Haven	*No Response*
RAS Aquaculture Research	*No Response*
Renewables UK & Renewables UK Cymru	*No Response*

Organisation	Action/ Response
RSPB	*Data for FAME and STAR projects could not be provided for this project as cannot be publicly published. However, potential to provide to WG depending on required use.*
Seabed User & Developer Group	No data to provide
SEACAMS (Bangor)	No data provided
SEACAMS (Swansea)	Paper and data supplied 'Callaway 2014'
SEAFISH	*No Response*
Seawatch Foundation/ MERP research	*No Response*
Severn Estuary Partnership	*No Response*
Shellfish Association of GB	*No Response*
Simply Blue Energy	No current data but may have some in 2019 – will highlight future existence.
SMRU Consulting	*No Response*
Tethys	*No Response*
The Crown Estate	*No Response*
Thomas Shellfish Ltd.	*No Response*
Tidal Lagoon Power	*No Response*
University of Liverpool	*No Response*
Wave Dragon	*No Response*
Wave Hub Ltd	*No Response*
Welsh Government	Link to Lle Geoportal provided

D Literature Evidence

Literature evidence database: Summary of key reference material providing evidence for the tidal stream, wave energy and aquaculture sectors.

Reference	Description	Source
Cefas (2018) Shellfisheries water quality.	Online maps of designated English shellfish waters	https://www.cefas.co.uk/cefas-data-hub/food-safety/shellfisheries-water-quality/
Cefas (2018) Shellfish Monitoring Results	Online: Map and results of shellfish monitoring	https://www.cefas.co.uk/cefas-data-hub/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/shellfish-monitoring-results/
Cefas (2018) Classification Zone maps	Online: Map showing classification results of shellfish production areas	https://www.cefas.co.uk/cefas-data-hub/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/classification-zone-maps/
Cefas (2018) Current Sampling Plans	Online: List of sampling stations and results of sampling shellfish waters	https://www.cefas.co.uk/cefas-data-hub/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/current-sampling-plans/
Cefas (2018) Annual report on the results of the biotoxin and phytoplankton official control monitoring programmes for England and Wales 2017. Cefas contract report FS115006/ C7473-C7474. March 2018	This report describes the results of the Official Control Biotoxin Monitoring Programme for England and Wales for the period 1st January to 31st December 2017.	https://www.cefas.co.uk/media/195989/c7473-c7474-fsa-year-1-2017-final.pdf
Cefas (2017) Annual report on the results of the biotoxin and phytoplankton official control monitoring programmes for England and Wales 2016. Cefas contract report FSA199 / C5666-C5667. March 2017	This report describes the results of the Official Control Biotoxin Monitoring Programme for England and Wales for the period 1st January to 31st December 2016.	https://www.cefas.co.uk/media/180293/c5667-fsa-year-5-2016-final-310317.pdf
Cefas (2016) Annual report on the results of the biotoxin and phytoplankton official control monitoring programmes for England and Wales 2015. Cefas contract report FSA199 / C5666-C5667. May 2016	This report describes the results of the Official Control Biotoxin Monitoring Programme for England and Wales for the period 1st January to 31st December 2015.	https://www.cefas.co.uk/media/53033/2015-england-and-wales-biotoxin-phytoplankton-offical-control-monitoring-annual-reportdoc.pdf
Cefas (2015) Annual report on the results of the biotoxin and phytoplankton official control monitoring programmes for England and Wales 2014. Cefas contract report FSA199 / C5666-C5667. May 2015	This report describes the results of the Official Control Biotoxin Monitoring Programme for England and Wales for the period 1st January to 31st December 2014.	https://www.cefas.co.uk/media/52943/c5667-fsa-year-3-2014-final-report-v1-1-pdf.pdf

Reference	Description	Source
Ellis, J.R. Cruz-Martines, A., Rackham, B.D. and Rogers, S.I. (2005) The distribution of chondrichtyan fishes around the British Isles and implications for conservation. *Journal of Northwest Fisheries Science.* 35: 195-213.	Over 50 species of chondrichthyan fishes are known from waters around the British Isles, of which 26 have been recorded in The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) trawl surveys. The distribution and relative abundance of dogfishes, skates and rays are described from groundfish surveys in the North Sea, English Channel, Irish Sea and Celtic Sea	http://journal.nafo.int/Portals/0/2005/5-ellis.pdf
Jones, E.L. and Russell, J.F. (2016) Updated grey seal (Halichoerus grypus) usage maps in the North Sea. Report to DECC. June 2016. Pp15	The Department of Business and Industrial Strategy (BEIS) funded a large deployment of tags on grey seals in the southern North Sea and subsequently commissioned an updated North Sea usage map reflecting the estimated grey seal population size in 2015	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/586446/SMRU_2016_Updated_grey_seal_usage_maps_in_the_North_Sea.pdf
Russell, D.J.F., Jones, E.L. and Morris. (2017) Updated Seal Usage Maps: The estimated at-sea distribution of Grey and Harbour seals. Scottish Marine and Freshwater Science. 8(25) pp30. *Scottish Government.* .	Maps providing estimates of Grey and harbour seal abundance (and associated confidence intervals) aggregated between 1988 and 2012, thus taking into account changes in population size through time.	https://data.marine.gov.scot/sites/default/files/SMFS%200825.pdf
Seafish (2018) Aquaculture profiles	Online site detailing key information on aquaculture species, Inc. production volumes, considerations for cultivation and governance.	http://www.seafish.org/aquacultureprofiles/
Waggitt, J.J., Dunn, H.K., Evans, P.G., Hiddink, J.G. et al. (2017) Regional-scale patterns in harbour porpoise occupancy of tidal stream environments. ICES Journal of Marine Science. doi:10.1093/icesjms/fsx164	As harbour porpoises *Phocoena phocoena* are abundant within tidal stream environments, mitigating population-level impacts from tidal stream energy extraction is considered a conservation priority. An understanding of their spatial and temporal occupancy of these habitats at a regional-scale will help steer installations towards locations which maximize energy returns but reduce the potential for interactions with populations. This study quantifies and compares relationships between the presence of harbour porpoise and several hydrodynamic characteristics across four tidal stream environments in Anglesey, UK.	http://www.seawatchfoundation.org.uk/wp-content/uploads/2017/11/Waggitt-et-al_2017.pdf
Waggitt, J.J., Robbins, A.M.C., Wade, H.M., Masden, E.A., Furness, R.W., Jackson, A.C. and Scott, B.E. (2017) Comparative studies reveal variability in the use of tidal stream environments by seabirds. Marine Policy. 81: 143-152.	The global increase in tidal stream turbine installations creates a need to identify and mitigate any impacts on seabird populations, such as black guillemots Cepphus grylle and European shags Phalacrocorax aristotelis. Identifying consistencies in their relative use of different microhabitats (fast versus slow mean horizontal current speeds) and tidal states (increasing/decreasing versus maximum currents) across these habitats could assist risk assessment and mitigation measures at both a regional and development site level.	https://www.researchgate.net/publication/315894224_Comparative_studies_reveal_variability_in_the_use_of_tidal_stream_environments_by_seabirds

Reference	Description	Source
Marine Ecosystems Research Programme	Top predator distribution maps and risk maps	http://www.marine-ecosystems.org.uk/Research_outcomes/Top_predators
Callaway, R. (2016) Historical data reveal 30-year persistence of benthic fauna associations in heavily modified waterbody. Frontiers in Marine Science.141(3): 1-13	The benthic environment of an industrialized embayment was investigated (Swansea Bay, Wales, UK) where it is proposed to build a tidal lagoon that would generate marine renewable energy from the tidal range. Since robust long-term baseline data was not available, the value of unpublished historical benthos information from 1984 by a regional water company was assessed with the aim to improve certainty about the persistence of current benthic community patterns.	

E GIS Outputs

E.1 Tidal stream and wave energy

E.1.1 Administrative boundaries

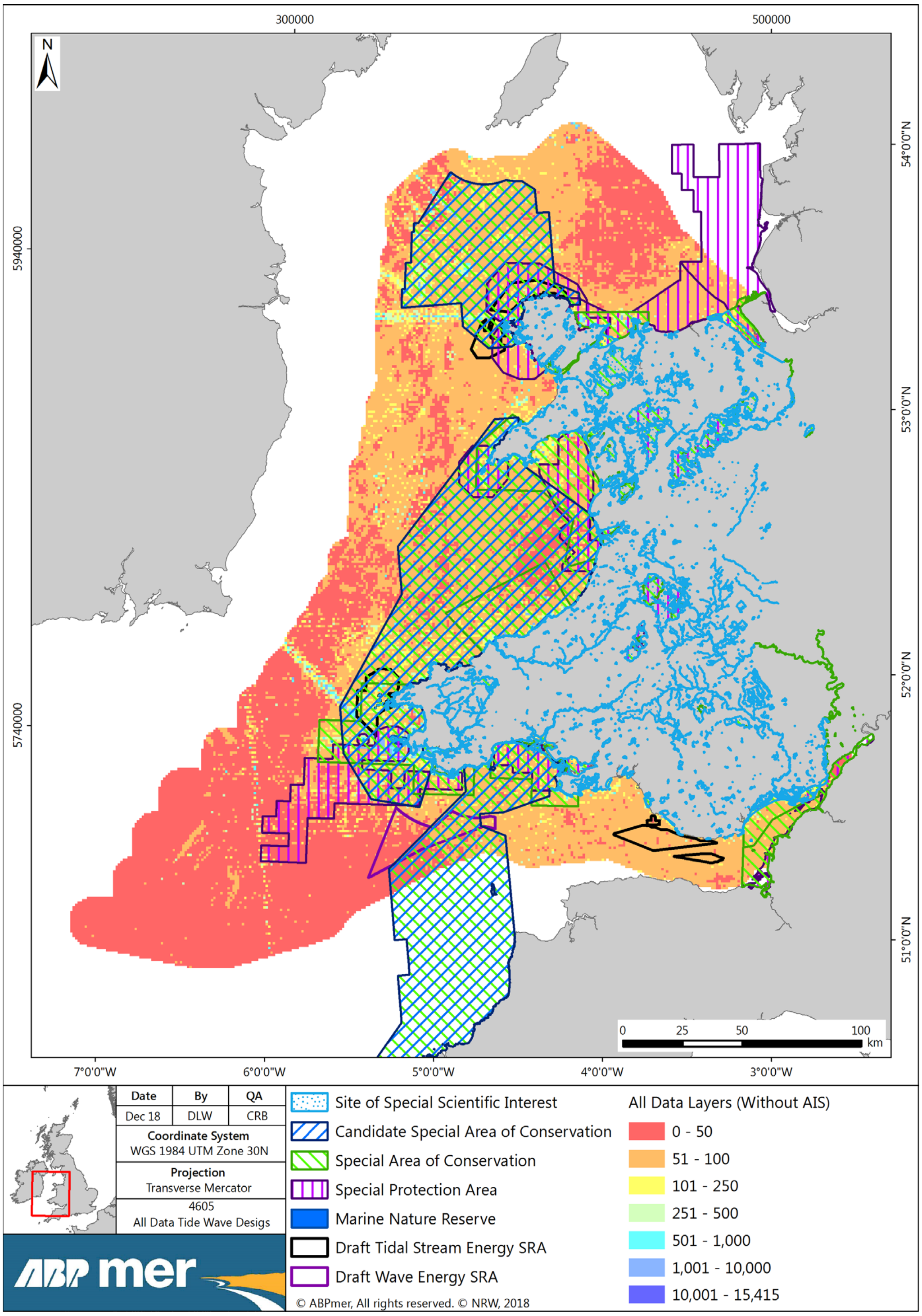


Figure E1. **Spatial coverage of high scoring data to inform tidal stream and wave energy developments showing designated areas (relative density per km²)**

E.1.2 Physical

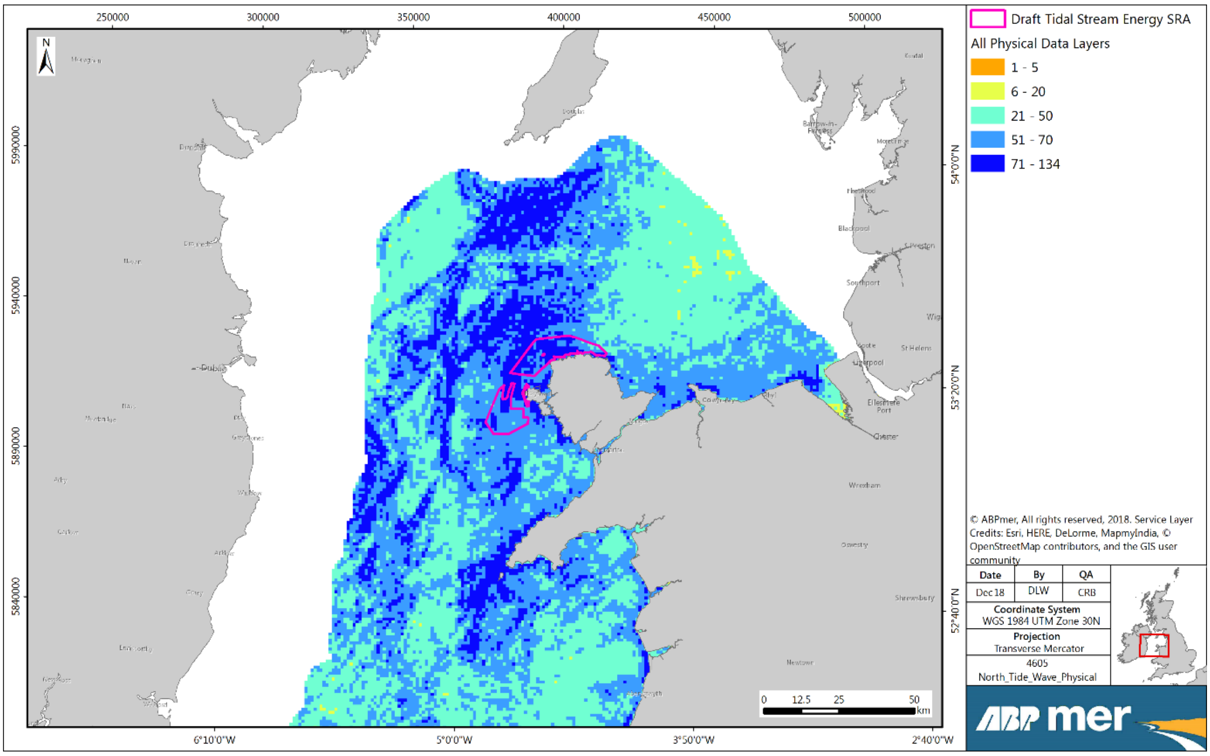


Figure E2. North Wales: Spatial coverage of high scoring physical data to inform tidal stream and wave energy developments (relative density per km²)

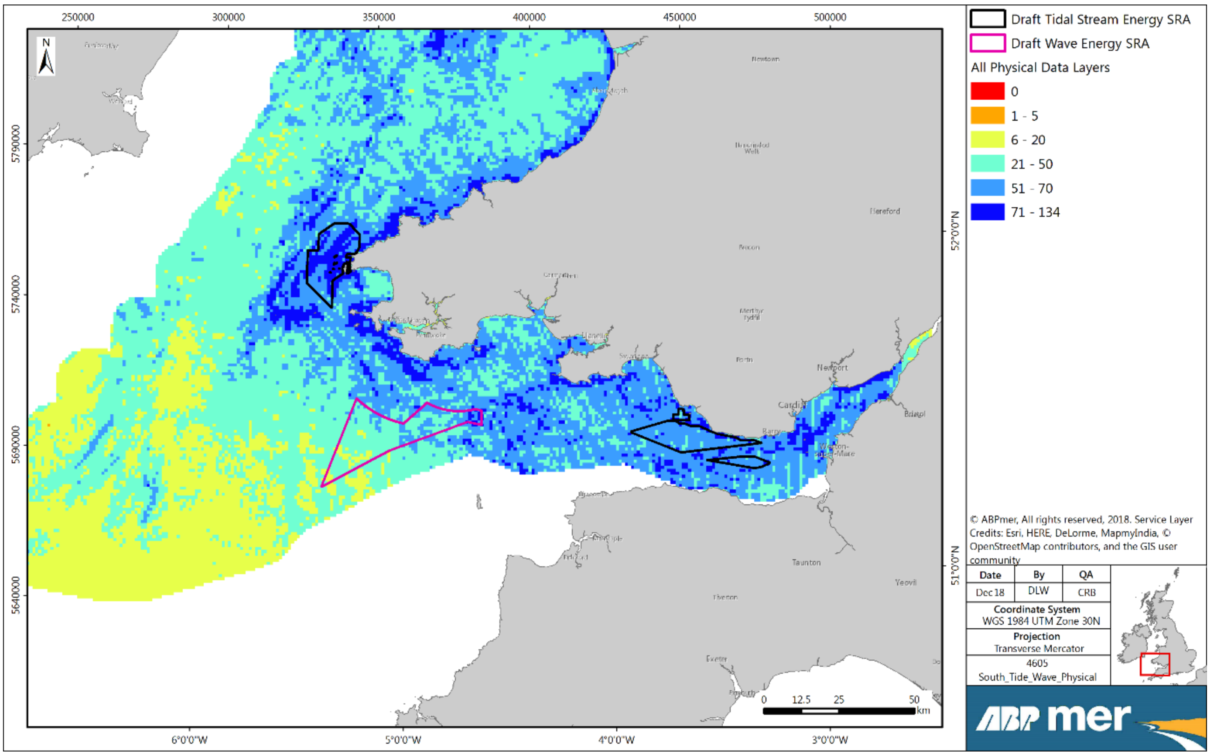


Figure E3. South Wales: Spatial coverage of high scoring physical data to inform tidal stream and wave energy developments (relative density per km²)

E.1.3 Chemical

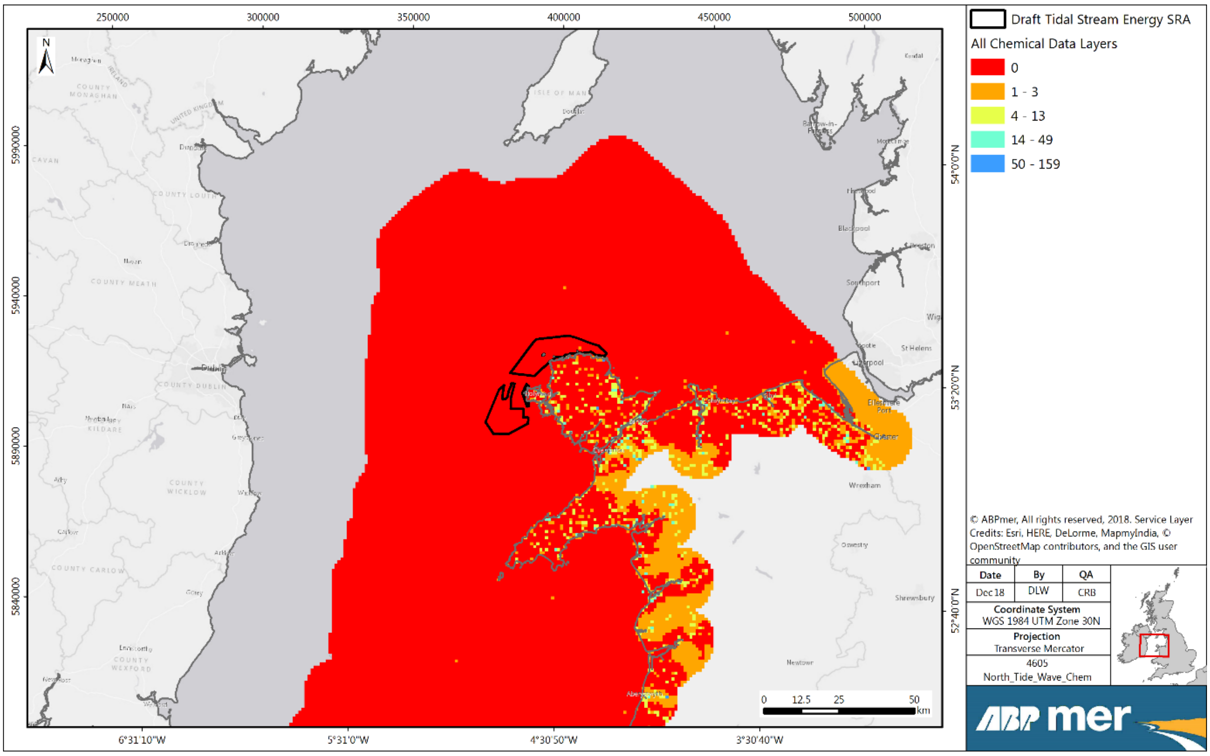


Figure E4. North Wales: Spatial coverage of high scoring chemical data to inform tidal stream and wave energy developments (relative density per km²)

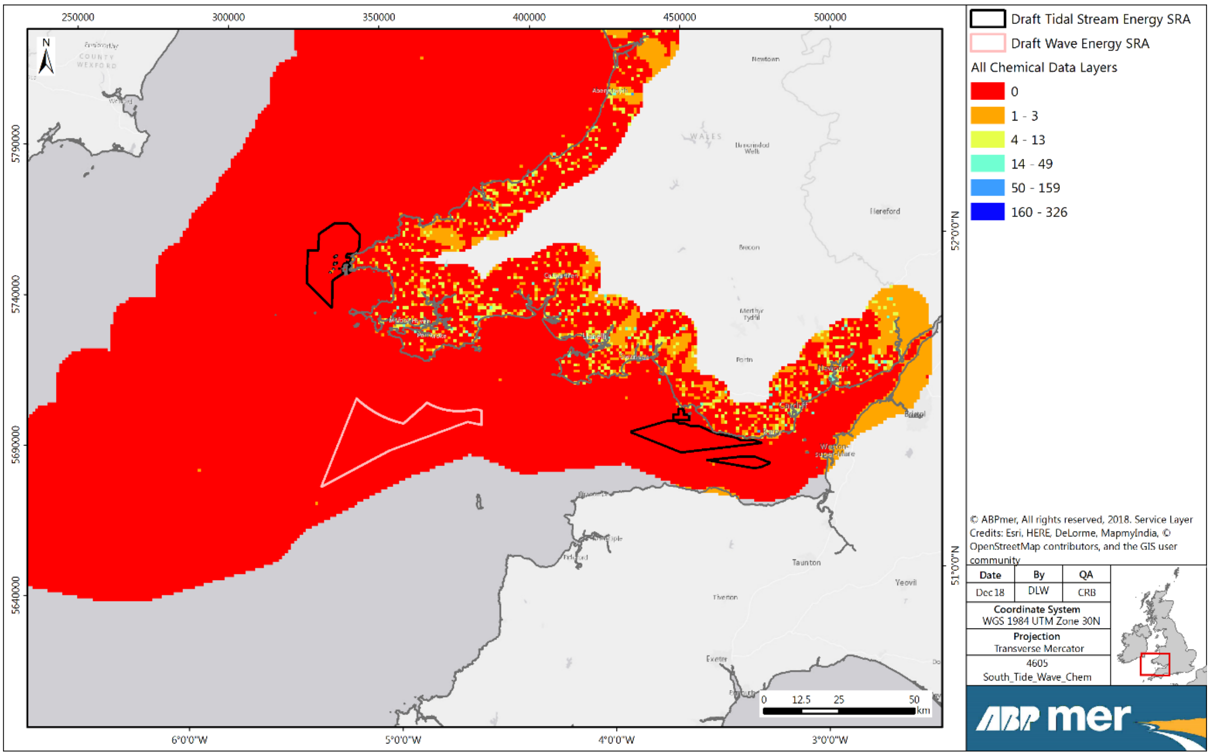


Figure E5. South Wales: Spatial coverage of high scoring chemical data to inform tidal stream and wave energy developments (relative density per km²)

E.1.4 Biological

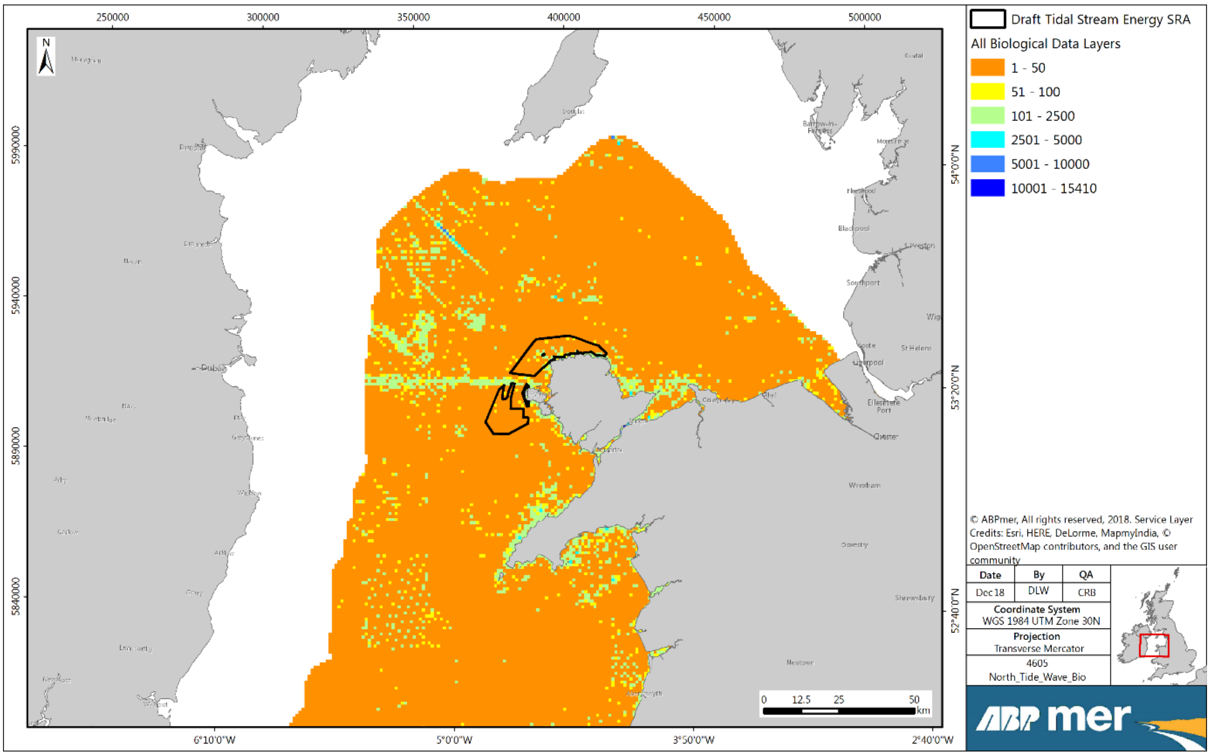


Figure E6. North Wales: Spatial coverage of high scoring biological data to inform tidal stream and wave energy developments (relative density per km^2)

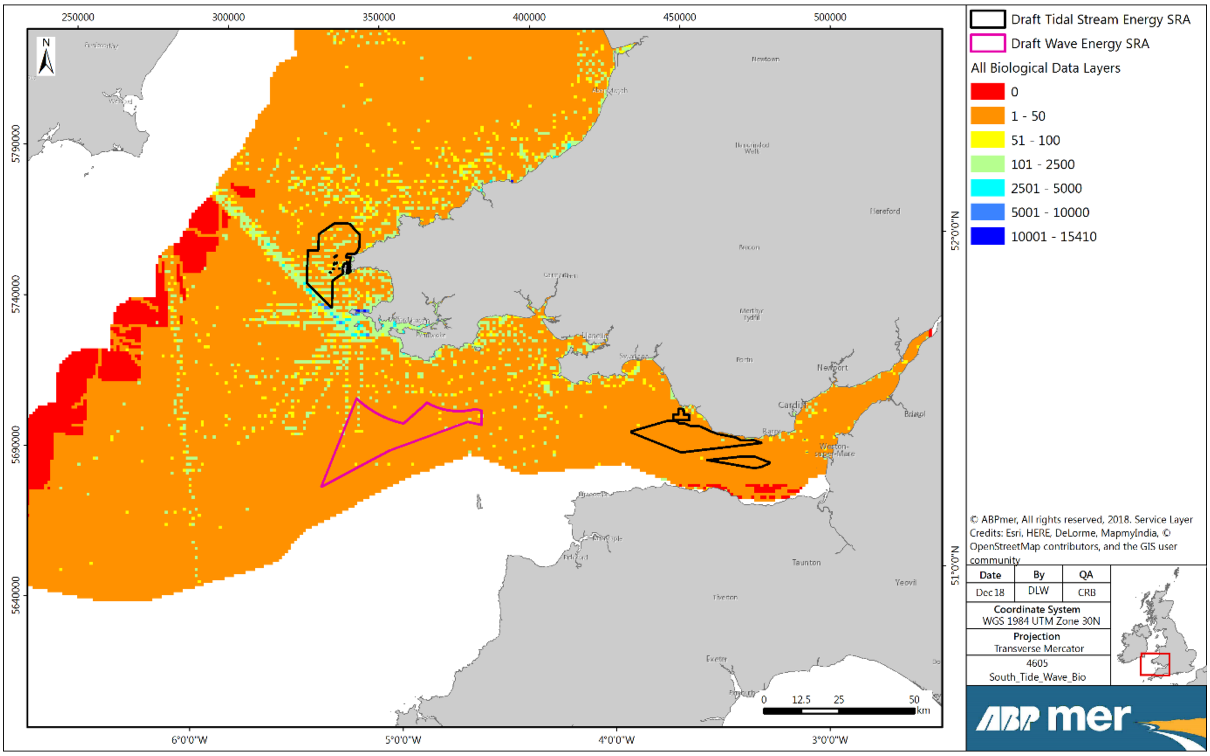


Figure E7. South Wales: Spatial coverage of high scoring biological data to inform tidal stream and wave energy developments (relative density per km^2)

E.1.5 Human environment

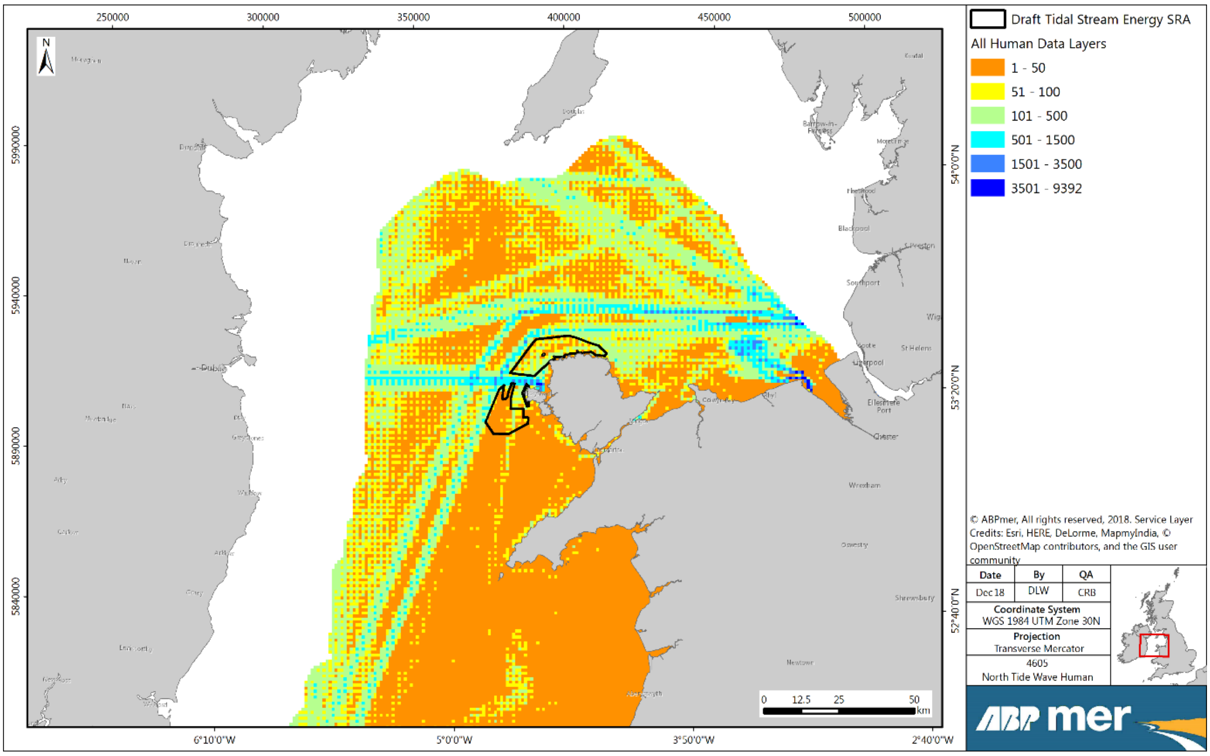


Figure E8. North Wales: Spatial coverage of high scoring human environment data to inform tidal stream and wave energy developments (relative density per km²)

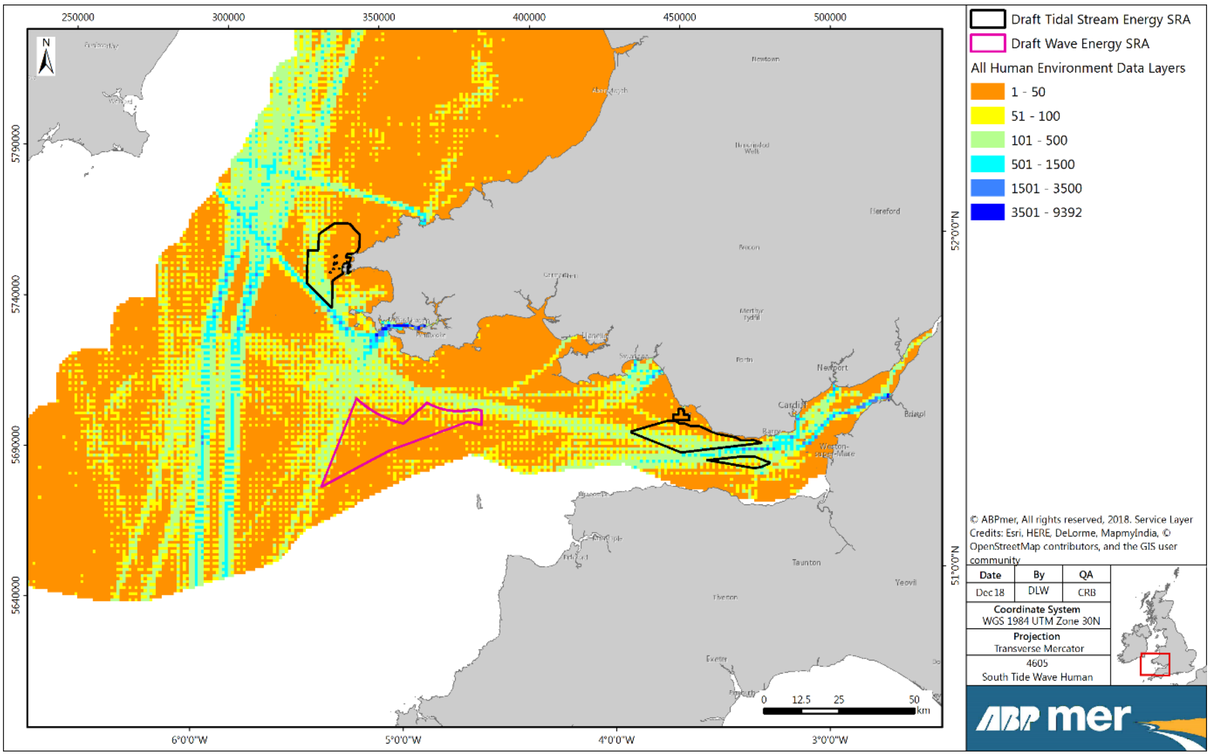


Figure E9. South Wales: Spatial coverage of high scoring human environment data to inform tidal stream and wave energy developments (relative density per km²)

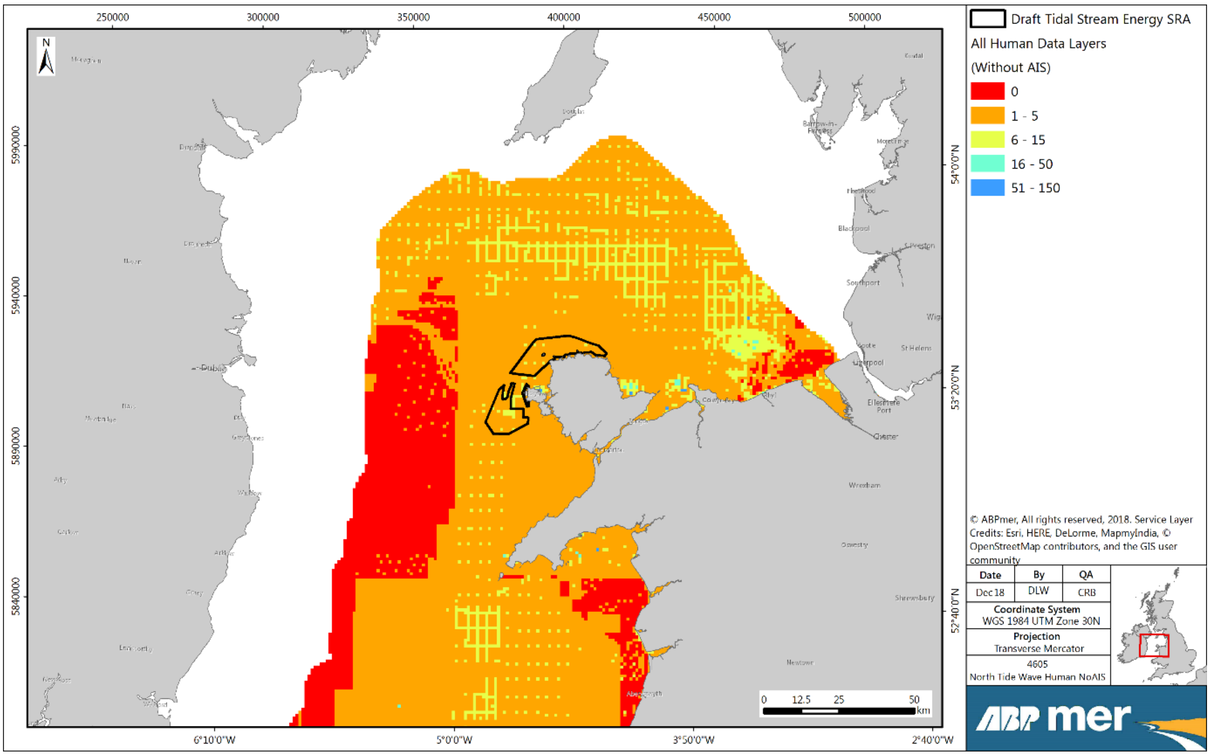


Figure E10. North Wales: Spatial coverage of high scoring human environment data, without AIS data, to inform tidal stream and wave energy developments (relative density per km²)

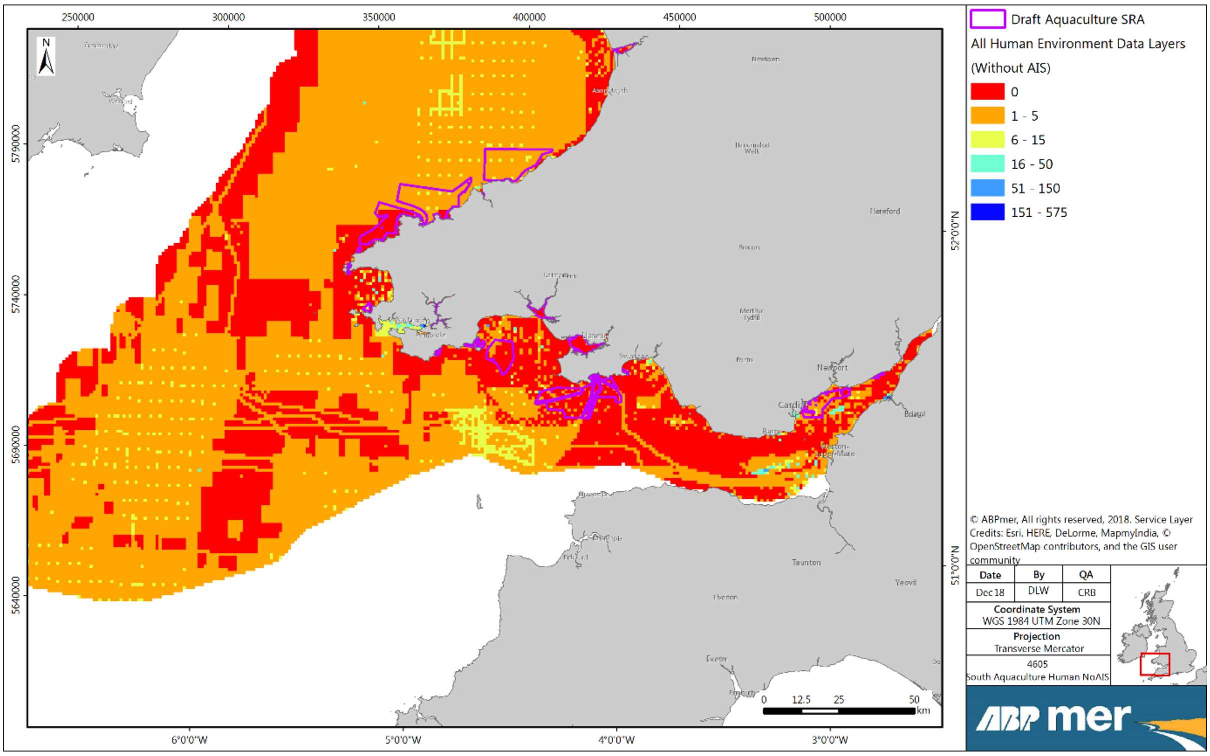


Figure E11. South Wales: Spatial coverage of high scoring human environment data, without AIS data, to inform tidal stream and wave energy developments (relative density per km²)

E.2 Aquaculture

E.2.1 Administrative boundaries

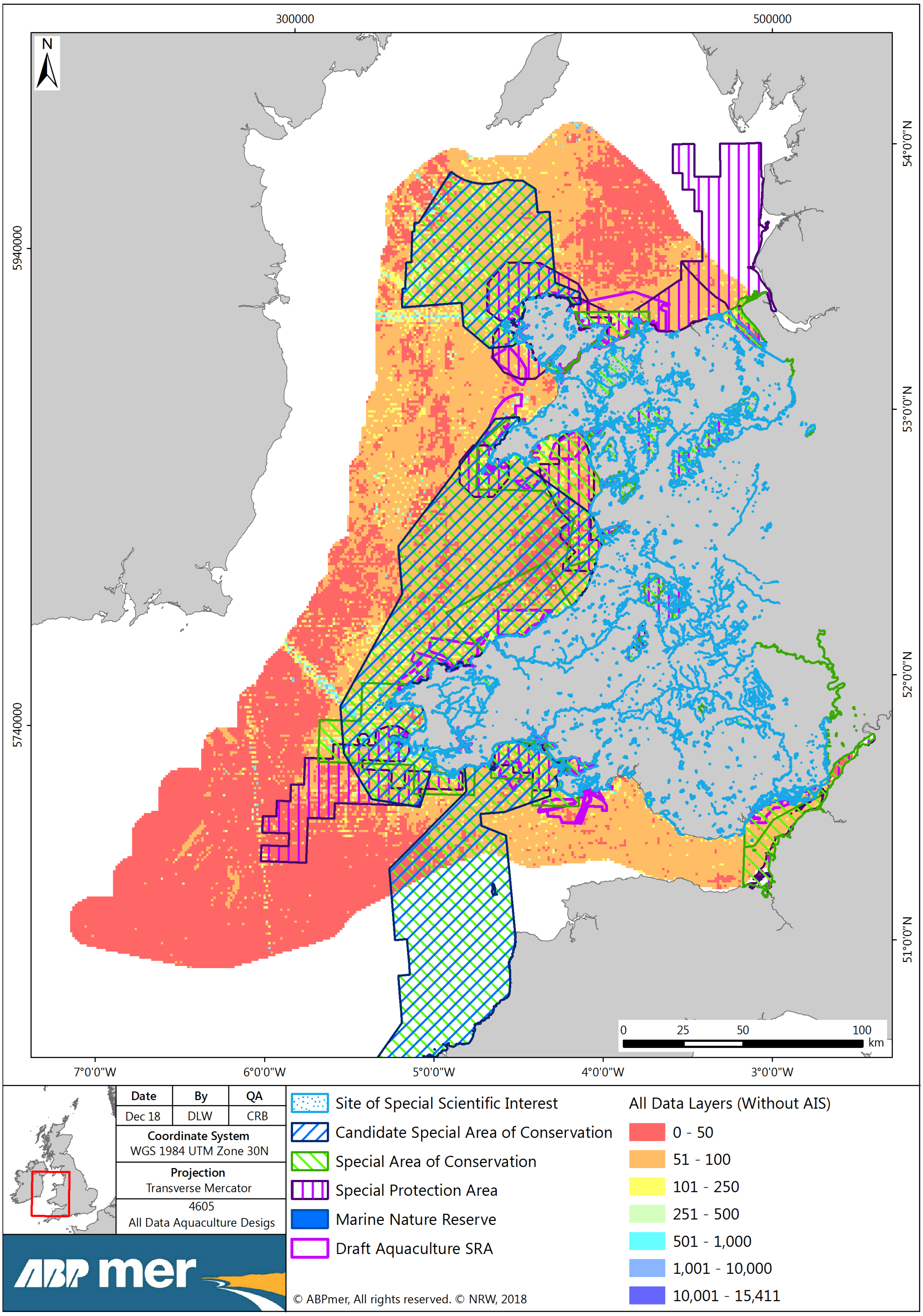


Figure E12. **Spatial coverage of high scoring data to inform aquaculture developments showing designated areas (relative density per km²)**

E.2.2 Physical

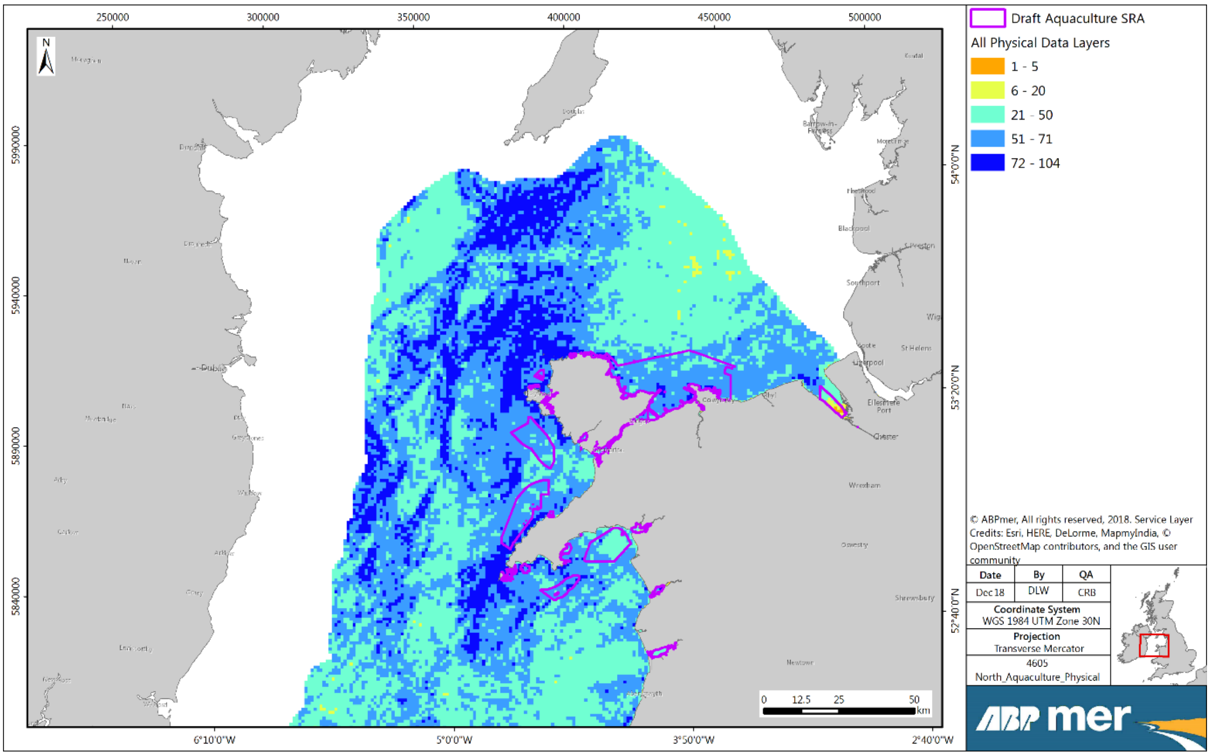


Figure E13. North Wales: Spatial coverage of high scoring physical data to inform aquaculture developments (relative density per km²)

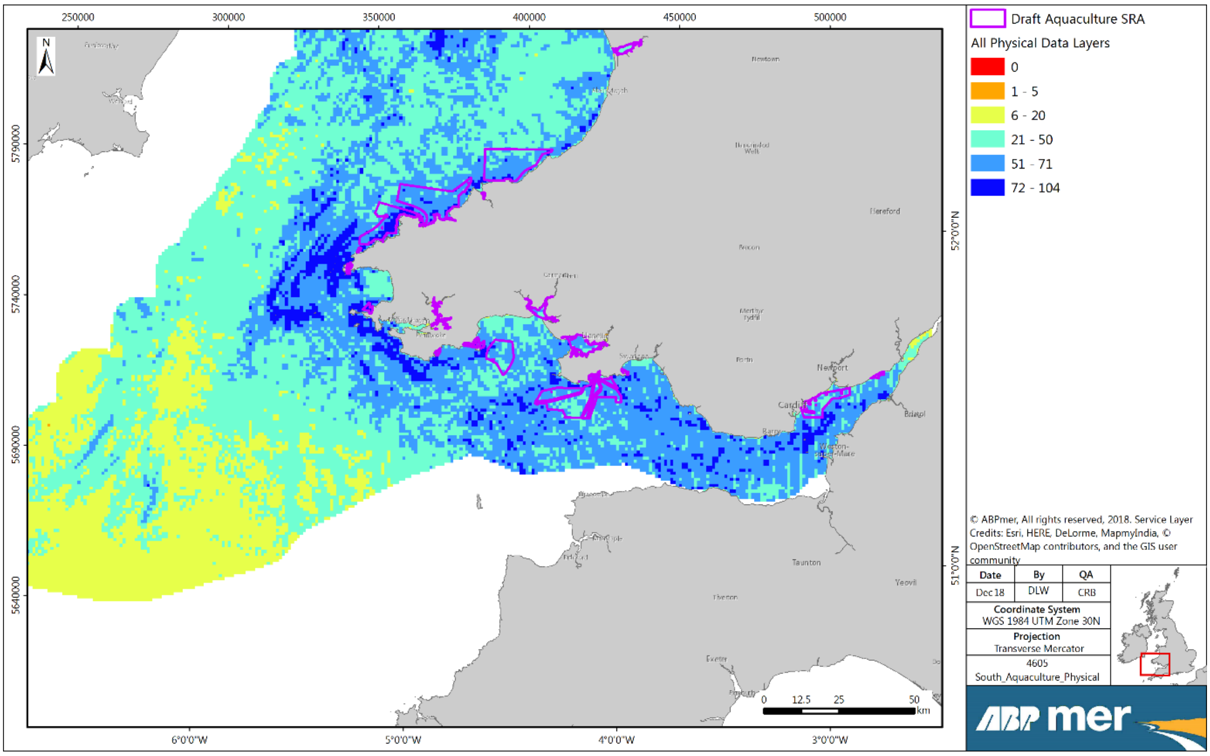


Figure E14. South Wales: Spatial coverage of high scoring physical data to inform aquaculture developments (relative density per km²)

E.2.3 Chemical

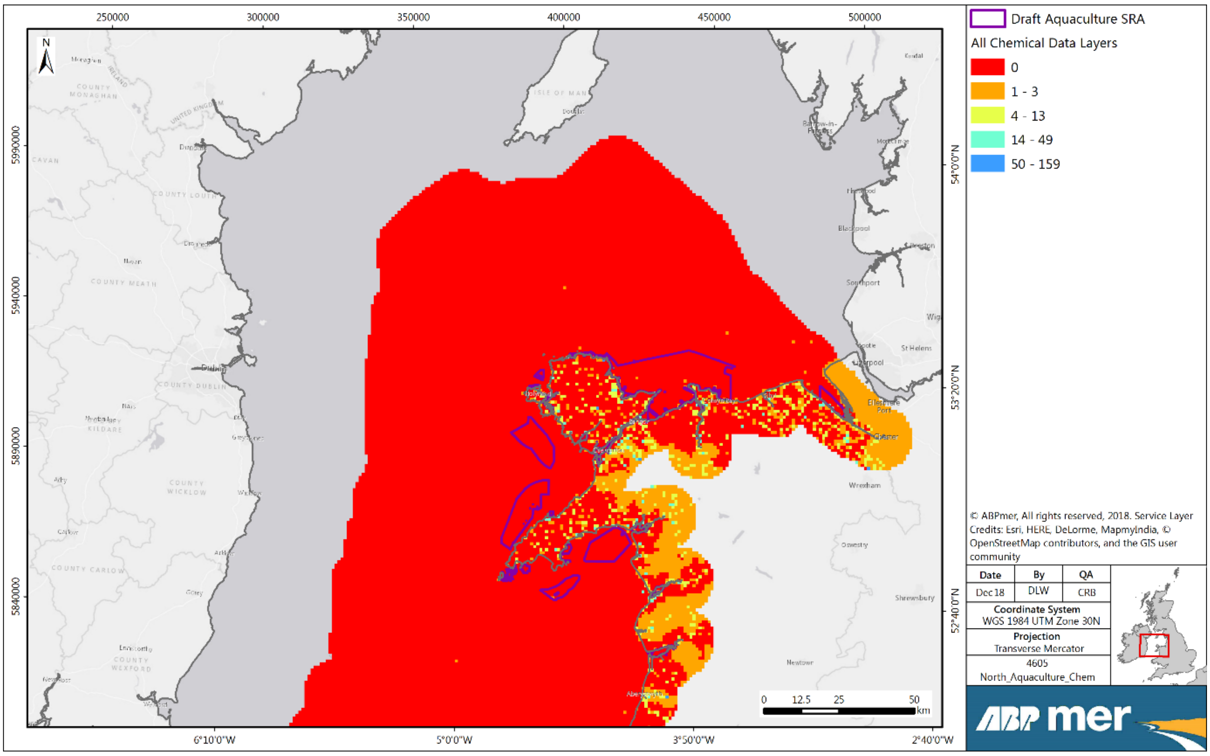


Figure E15. North Wales: Spatial coverage of high scoring chemical data to inform aquaculture developments (relative density per km²)

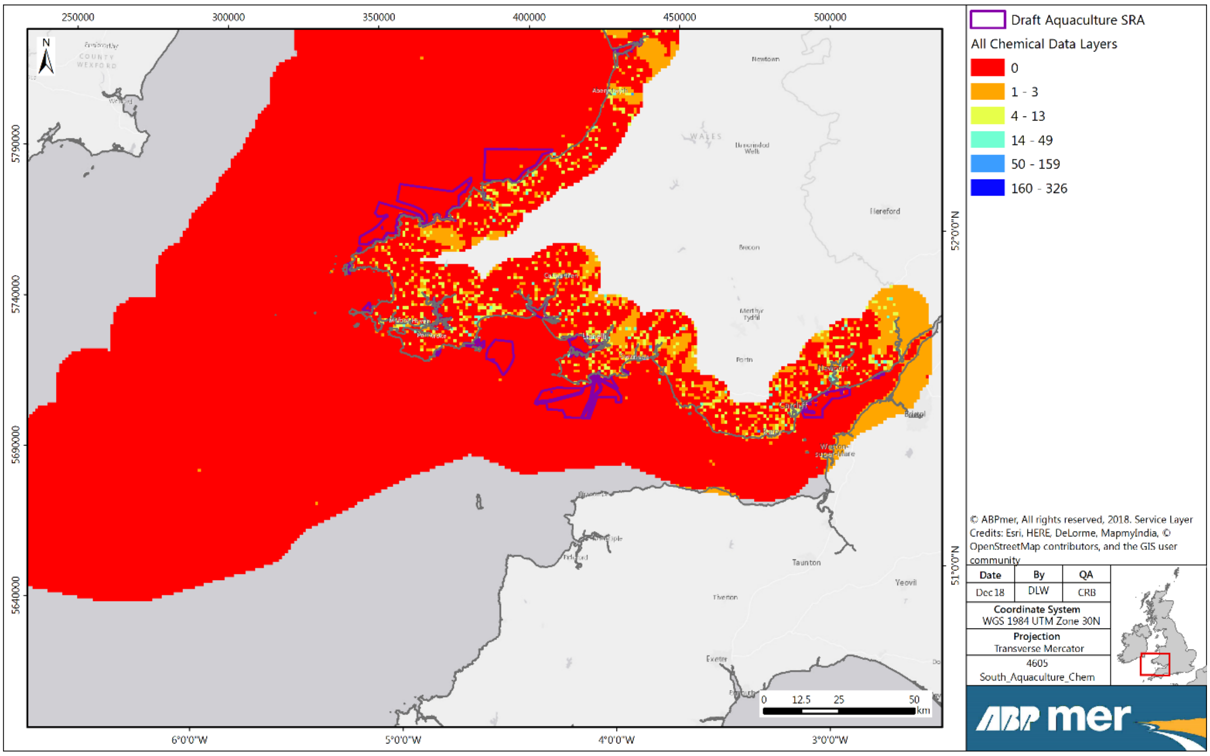


Figure E16. South Wales: Spatial coverage of high scoring chemical data to inform aquaculture developments (relative density per km²)

E.2.4 Biological

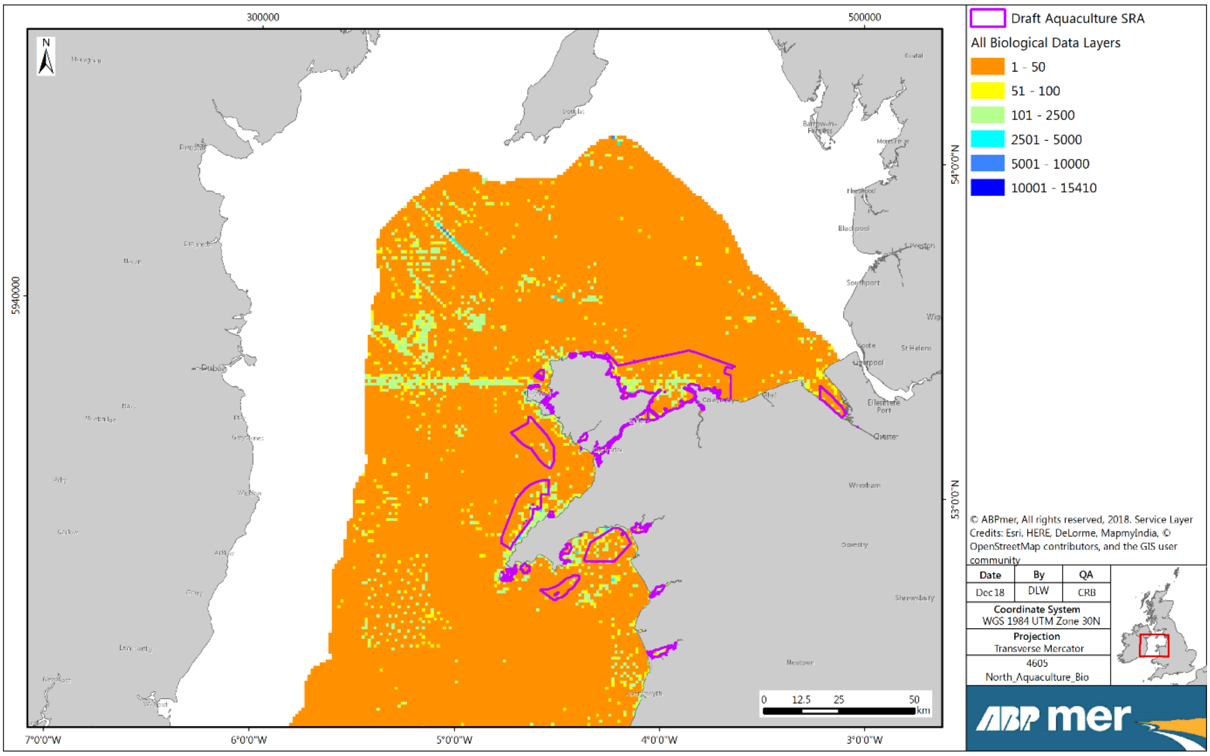


Figure E17. North Wales: Spatial coverage of high scoring biological data to inform aquaculture developments (relative density per km²)

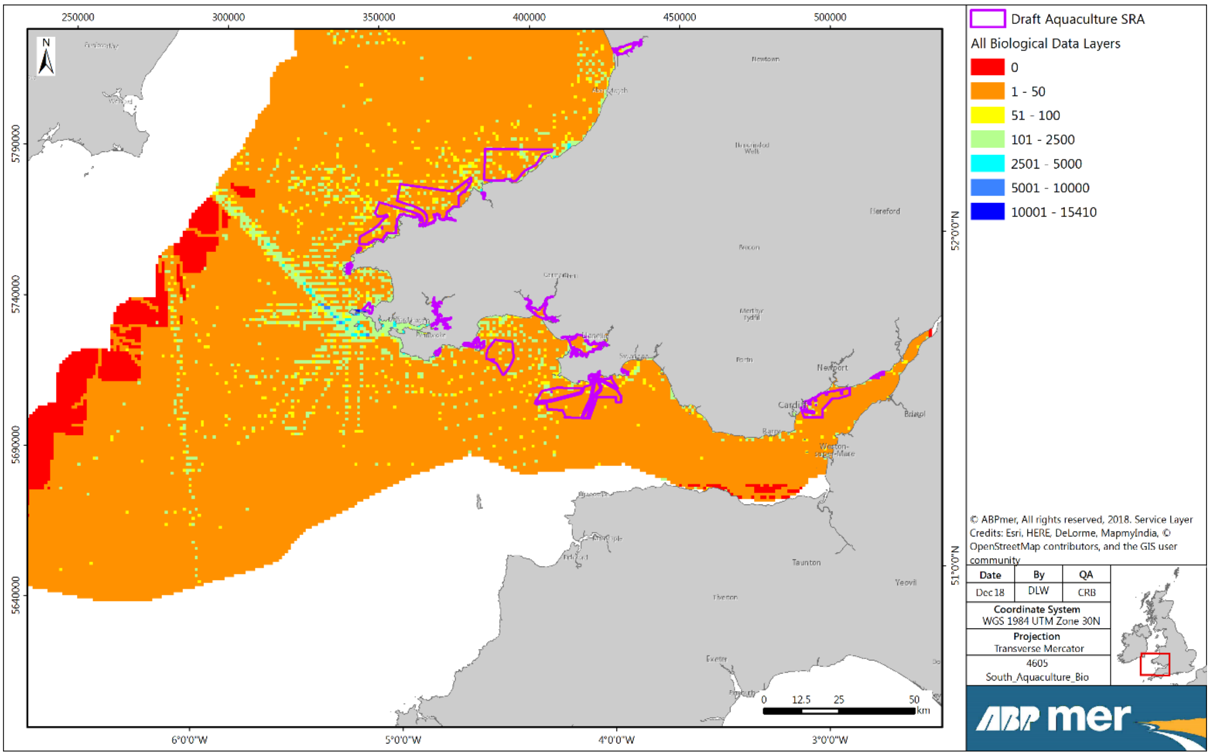


Figure E18. South Wales: Spatial coverage of high scoring biological data to inform aquaculture developments (relative density per km²)

E.2.5 Human environment

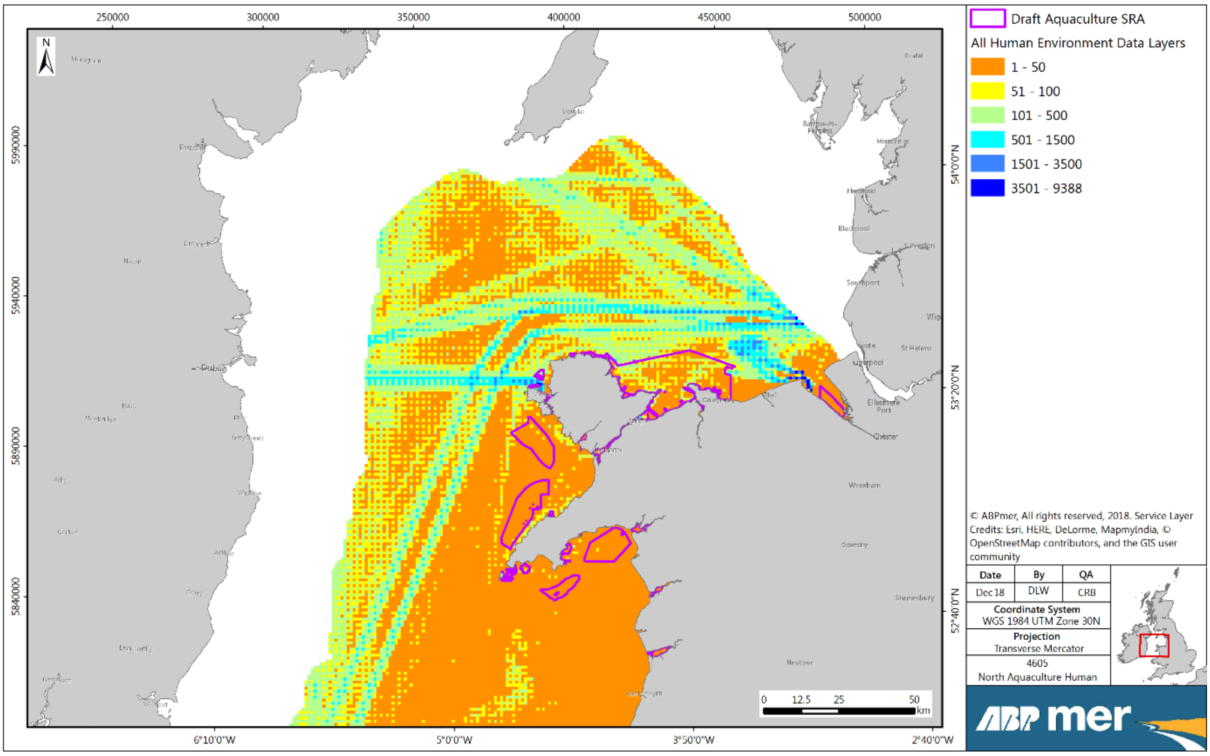


Figure E19. North Wales: Spatial coverage of high scoring human environment data to inform aquaculture developments (relative density per km²)

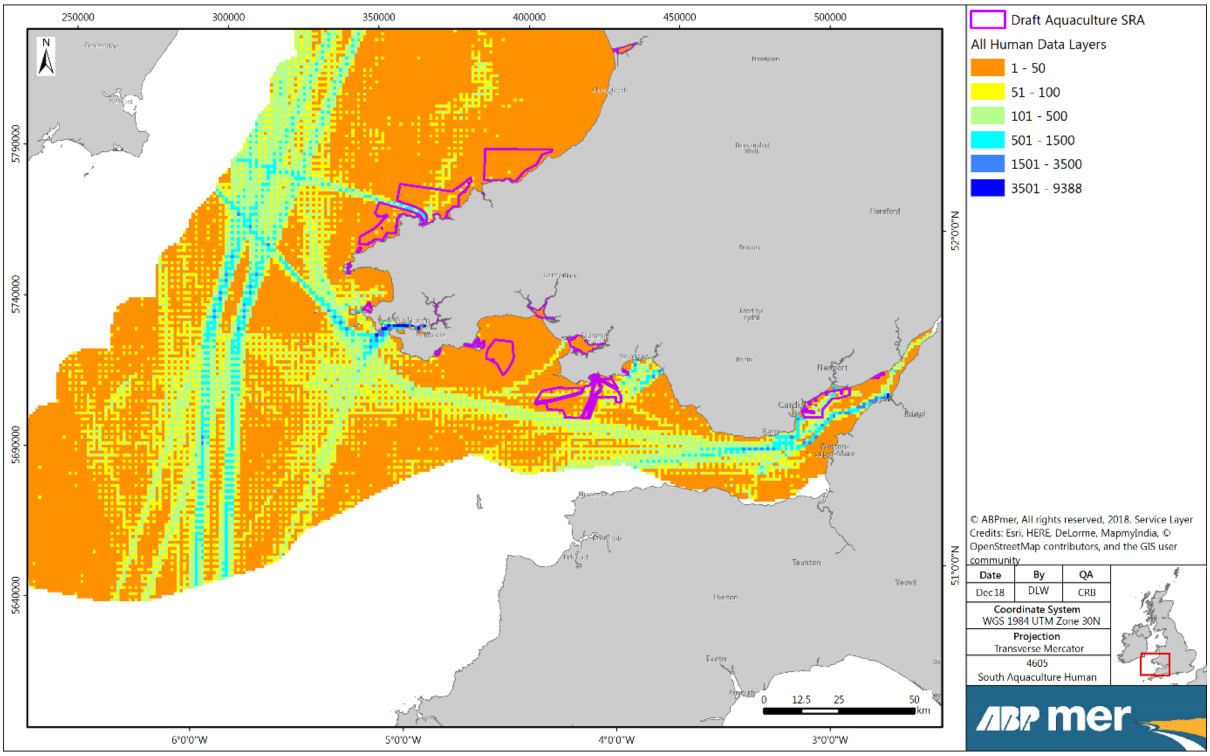


Figure E20. South Wales: Spatial coverage of high scoring human environment data to inform aquaculture developments (relative density per km²)

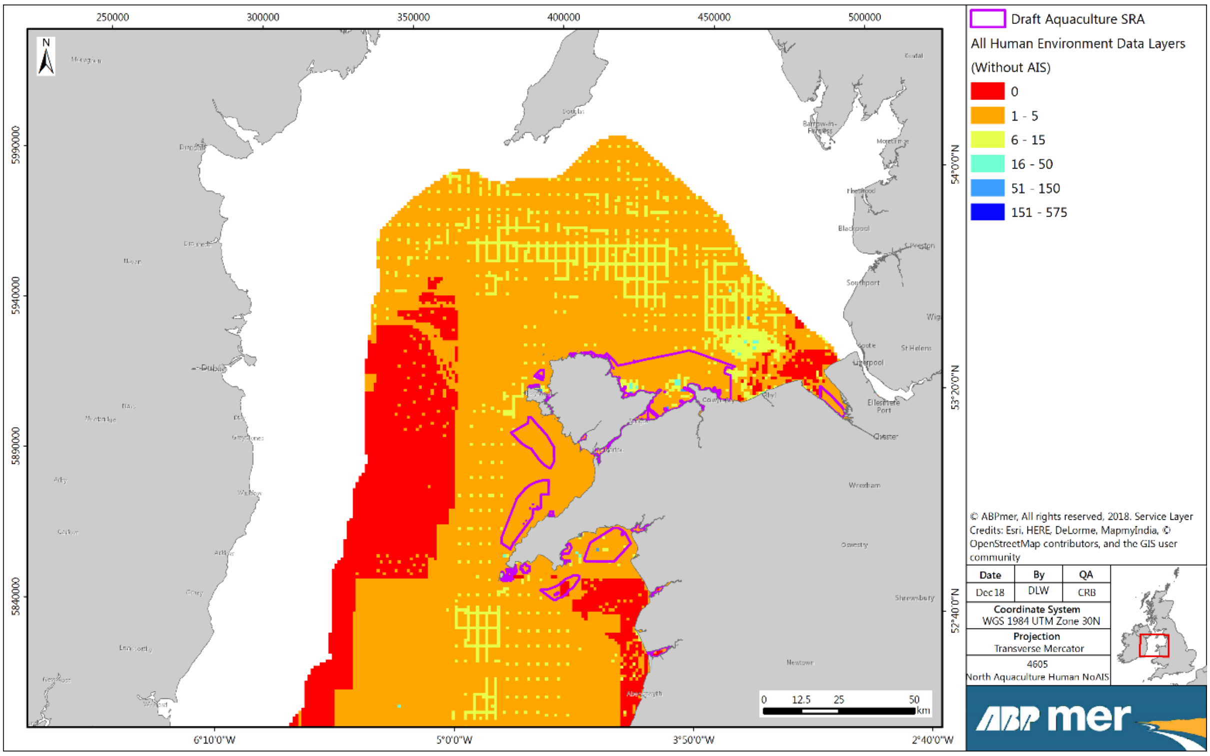


Figure E21. North Wales: Spatial coverage of high scoring human environment data without AIS data to inform aquaculture developments (relative density per km²)

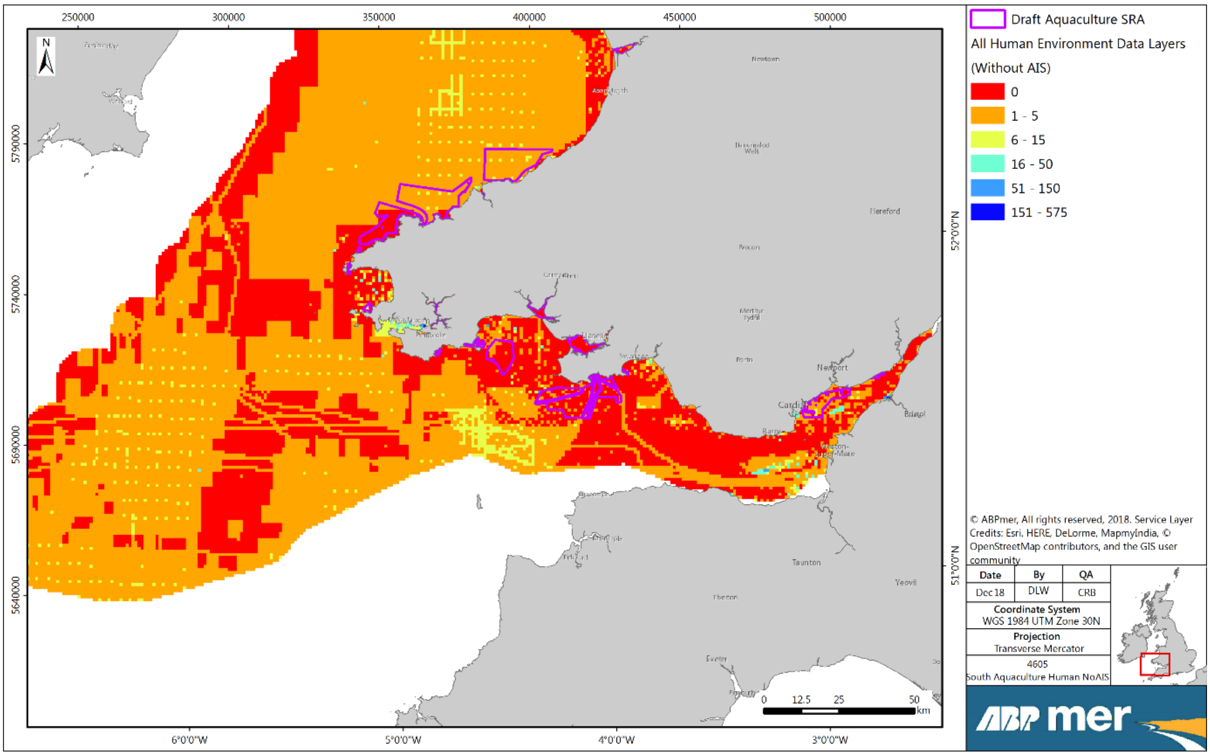


Figure E22. South Wales: Spatial coverage of high scoring human environment data without AIS data to inform aquaculture developments (relative density per km²)

F Specific Impact Pathways: Evidence Review

F.1 Tidal Stream Energy

Evidence Review	Tidal Stream Energy				
Impact Pathway	**Indirect effects on marine features as a consequence of changes to coastal processes** Operation of the tidal turbine(s) will result in the removal of energy from the hydrodynamic system. The presence of the turbine(s) will also change the local hydrodynamics. This pathway will change local currents and sediment transport, with the potential to also affect wave climate. Resultant effects from changes to hydrodynamics have the potential to affect sediment transport regime and hence morphology of seabed and coastal features. Changes to flow direction and velocity also have the potential to affect water quality such as through changes to suspended sediment concentrations. Changes to flow regimes within estuaries is of particular concern due to their influence on tidal flushing, potential wave propagation and sediment budget. Changes in tidal flushing can change the sediment dynamics and may lead to changing patterns of deposition and erosion. Indirectly, the changes in hydrodynamics and sediment transport can lead to changes in community composition and habitat type.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
SeaGen Tidal Turbine installation using twin 16 m diameter rotors	Strangford Lough Narrows, Northern Ireland	Flow velocity / turbulence	Benthic surveys (2005 and March 2008)	Benthic surveys (July 2008, March 2009, July 2009 and April 2010)	The study concluded that the operating turbine did not modify the flow dynamics, scour patterns, or turbulence characteristics of the Strangford Narrows such that it affected benthic community. However, flow velocities were decreased, and the surface wake was measurable 300 m downstream
Roosevelt Island Tidal Energy (RITE) Project Demonstration Grid-connected demonstration array of six Kinetic Hydropower System (KHPS) turbines	East Channel of East River - New York, NY, USA	Geotechnical Seabed and Substrate Composition	Side scan SONAR, sub-bottom SONAR, video grab samples. Stationary ADCPs within field. Mobile ADCP surveys.	Results of modelling used to scope out requirement for seabed post-consent monitoring.	No sediment deposition expected in modelled scenario due to high tidal velocities and aquatic habitat limited to transient use. Modelling data supported by ADCP data concluded that the installation was unlikely to cause measurable changes in the water flow or other associated physical changes.

Evidence Review Tidal Stream Energy					
Minesto Deep Green Holyhead Deep Project (EIA)	Holyhead Deep, Irish Sea, NW Wales.	Physical processes and seabed morphology	Geophysical survey; environmental survey; multibeam bathymetry; ADCP deployment; tidal resource modelling; numerical modelling of sediment transport in Holyhead Deep	N/A	Results of historic survey and modelling studies supplemented with additional geophysical and environmental surveys used to scope out the following from EIA assessment: effects on wave climate effects on local currents effects on offshore sediment transport and morphology; effects on tidal resource.
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study limitations**	**Study Conclusions**
Ahmadian, R., R. Falconer, and B. Bockelmann-Evans (2012), "Far-field modelling of the hydro-environmental impact of tidal stream turbines," Renewable Energy, 38:107-116,	Severn Estuary	Flow velocities and sediment transport	Modelling study using Severn Estuary	Model unable to be tested against measured data.	A turbine array in the Severn Estuary has the potential to reduce flow rates up and downstream of the array, whilst increasing flow rates along the sides of the array. Additionally, sediment concentrations (and associated faecal bacteria) were increased within 15 km of the turbine array
Haverson, D.; Bacon, J.; Smith, H.; Venugopal, V.; Xiao, Q. (2018). Modelling the Hydrodynamic and Morphological Impacts of a Tidal Stream Development in Ramsey Sound. Renewable Energy, 126, 876-887.	Ramsey Sound, Wales	Hydrodynamics / Sediment	Directly applicable to WNMP	The study is unable to assess quantitative changes to sediment transport and therefore provides a qualitative discussion only.	The changes modelled indicate that the array will lead to localised sediment accumulation and act as a barrier to sediment transport with potential consequences for benthic ecology in the region
R. Martin-Short, J. Hill, S.C. Kramer, A. Avdis, P.A. Allison, M.D. Piggott (2015), Tidal resource extraction in the Pentland Firth, UK: Potential impacts on flow regime and sediment transport in the Inner Sound of Stroma, Renewable Energy Vol 76 pp 596-607.	Modelling Pentland Firth (Inner Sound of Stroma)	Hydrodynamics / Sediment	Sediment responses to Tidal Energy Array	Specific to study location and modelling study only, not validated.	Sizeable (>85) arrays of tidal energy turbines have the potential to affect bed shear stress distributions in such a way that sediment accumulation / scour are modified within the modelled system.

Evidence Review	Tidal Stream Energy				
Yang, Z. et al. 2013. Modelling tidal stream energy extraction and its effects on transport processes in a tidal channel and bay system using a three-dimensional coastal ocean model	Theoretical estuary basin	Circulation hydrodynamics	Theoretical model of a macro-tidal estuary basin to determine effects of tidal turbines on hydrodynamic processes	Turbine supporting structures not considered (i.e. turbulence around foundation structures)	Tidal arrays can increase flushing times of an estuary basin, potentially reducing water quality and mixing rates. Flushing time increases exponentially compared to volume flux reductions which are traditionally used in environmental assessments.
G. I. Shapiro. 2011. Effect of tidal stream power generation on the region-wide circulation in a shallow sea.	Theoretical shallow sea (based on Celtic Sea)	Circulation hydrodynamics	Theoretical model, using Celtic Sea- Findings are applicable to Welsh coastline	Numerical values should be considered purely as examples. Residual currents could vary with season / annually depending on weather dependent wind driven and seasonal density driven components.	The impact on hydrodynamic processes would vary significantly dependant on the shape, size and location of any array
Copping, A., et al. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/ Limitations			
Type of Uncertainty / Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**
Uncertainty	Irrespective of the pre-existing data and evidence there will always be uncertainties of the potential effect on physical processes which can only be predicted through modelling	Physical processes and seabed morphology	Modelling carried out based on physical site-specific data and proposal specifications. MLP/2014/00383
Limitation	There is limited physical data available from installed turbines that can be used to validate models at either small or large scales.	Sediment Transport / Hydrodynamics	Collection of physical data during operation of the tidal array will provide a mechanism for validation of predicted changes and hence allow refinement of models. This will increase confidence in predictions.
Limitation	The potential for far-field effects on coastal morphology are difficult to predict or monitor.	Sediment morphology	Careful selection of site away from dynamic bedforms. Greater understanding of the wider sediment transport system.

Remarks

There is unlikely to be existing evidence or data available that would negate the requirement for rigorous baseline data collection and detailed hydrodynamic and sediment transport modelling for a given tidal stream proposal. Consideration of the multitude of variables can only be addressed through predictive modelling to assess the potential effects from changes on physical processes.

Confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results.

As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

Evidence Review	Tidal Stream Energy				
Impact Pathway	**Collision of mobile marine features resulting in injury or mortality** The presence of tidal turbines has the potential to result in injury or mortality to marine mammals, fish and diving birds.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
SeaGen Tidal Turbine installation using twin 16 m diameter rotors	Strangford Lough Narrows, Northern Ireland	Marine Mammals / Birds	Shore based survey, Passive acoustic monitoring, Aerial survey, harbour seal telemetry, Underwater noise monitoring and active sonar.	Shore based survey, Passive acoustic monitoring, Aerial survey, harbour seal telemetry, Underwater noise monitoring, active sonar and carcass post mortems.	The study concluded that no major impacts were detected across the 3 years of post-installation monitoring. There were relatively small scale changes in the behaviour and distribution of seals and harbour porpoises, suggestive of a degree of local avoidance.
OpenHydro European Marine Energy Centre Series of 6 m open-centre tidal turbines.	Fall of Warness, Orkney, Scotland	Fish	N/A	Video footage taken at the face of the pile-mounted turbine, supplemented by observations of marine mammals and seabirds from land-based observers using binoculars and spotter scopes (Daytime only)	No marine mammals have been observed interacting with the turbines, but seals, porpoises, and small whales are frequently observed transiting through the region. Fish, began to visit the lee side of the turbine after the first year to graze on vegetation attached to the structure while the blades were not moving. As tidal currents picked up and the turbine began to rotate, the fish appeared to leave the area. In the video analysis to date, no fish have been observed swimming through the turbine while the turbine is rotating and no fish strike mortality has been observed.
Ocean Renewable Power Company Cobscook Bay Tidal Energy Project Three cross-axis turbine generator units in 26 m of water.	Cobscook Bay, Maine, USA	Fish	Characterisation of population using trawls, nets and traps	Dual-Frequency Identification Sonar [DIDSON]) cameras were mounted fore and aft of the turbine, angled to observe a cross section of the device over a 24 hr period	Fish did not entirely avoid the area occupied by the turbine. Results from the study showed that a higher proportion of fish interacted with the turbine when it was still than when it was rotating and that during these interactions the predominant behaviour was fish entering the turbine. The study was not able to discover the disposition of the fish that passed through the turbine,

Evidence Review Tidal Stream Energy					
					although there were no incidences of dead or dying fish recorded after passage through the operating turbine.
Roosevelt Island Tidal Energy (RITE) Project Demonstration Grid-connected demonstration array of six Kinetic Hydropower System (KHPS) turbines	East Channel of East River - New York, NY, USA	Geotechnical Seabed and Substrate Composition	24 acoustic cameras (split-beam transducers [SBTs]), mobile SBT transect surveys, DIDSON systems, and vessel- and shore-based observations of bird activity	24 acoustic cameras (split-beam transducers [SBTs]), mobile SBT transect surveys, DIDSON systems, and vessel- and shore-based observations of bird activity.	The data indicated that fish behaviour appeared to be primarily influenced by the natural tidal currents and secondarily by the presence of the operating turbines. The data suggested that fish were able to detect and successfully pass around the operating turbines. Observers did not see a change in bird abundance or behaviour around the project area.
MyGen Tidal Energy Project – Phase 1	Inner Sound, Pentland Firth, Scotland	Diving birds, marine mammals and fish of conservation concern	Baseline monitoring relies upon previously undertaken surveys, reported in the MyGen Tidal Energy Project Phase 1 Environmental Statement.	Multibeam sonar; Passive Acoustic Monitoring (PAM); TSS mounted video camera, Harbour seal telemetry, FLOWBEC platform, TTG mounted ADCP, TTG mounted video camera and Blade strain gauge.	N/A – Data not yet available,
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study limitations**	**Study Conclusions**
B Band, C Sparling, D Thompson, J Onoufriou, E San Martin and N West (2016); Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines. Scottish Marine and Freshwater Science Vol 7 No 17.	Pentland Firth / EMEC (Fall of Warness)	Harbour Seals	Assessment of models for harbour collision risk assessment	Limited to a single turbine type with location specific data. Does not take into account avoidance behaviour.	Modelled data suggested some mortality as consequence of tidal turbines
Mark Bevelhimer, Constantin Scherelis, Jonathan Colby & Mary Ann Adonizio (2017) Hydroacoustic Assessment of Behavioral Responses by Fish Passing Near an Operating Tidal Turbine in the East River, New York, Transactions of the American Fisheries Society, 146:5, 1028-1042	East River, New York	Fish	Direct- measurements of fish behaviour around tidal turbines	Avoidance behaviour appeared to be initiated beyond the range of the detection system	Suggestion that there is considerable avoidance behaviour around the turbines. Fish density approx. halved when turbine was installed / operational. No evidence observed for fish being struck by turbine blades.

Evidence Review Tidal Stream Energy					
Amaral, S.V., Bevelhimer, M.S., Čada, G.F., Giza, D.J., Jacobson, P.T., McMahon, B.J., and Pracheil, B.M. 2015. Evaluation of Behavior and Survival of Fish Exposed to an Axial-Flow Hydrokinetic Turbine, North American Journal of Fisheries Management 35(1):97–113	Laboratory Based	Fish	Study used 3 species of fish, may not be applicable to all species present in proposed development areas.	Only investigates a 7 blade 1.5 m turbine which is unlikely to be the proposed technology for a full scale installation.	Survival rates for fish passing through the turbines were greater than 95% for all trials. Few injuries were seen in the experimental fish and most of them were not attributed to passage through the turbine-swept area
Macaulay, J.; Malinka, C.; Coram, A.; Gordon, J.; Northridge, S. (2015). MR7.1.2 The Density and Behaviour of Marine Mammals in Tidal Rapids. Report by Sea Mammal Research Unit (SMRU). pp 53.	Six sites around the Scottish coasts	Porpoises	Indication of sea mammal activity in tidal areas.	Less than one and a half weeks of continuous data have been collected, all during the summer and mostly during daylight hours	Porpoises spent 75% of time in the upper 38-40 m of the water column. Variation between sites emphasised requirement for site specific data collection.
Wilson, B. R.S. Batty, F. Daunt, and C. Carter (2007), Collision risks between marine renewable energy devices and mammals, fish and diving birds," Report to the Scottish Executive, Scottish Association for Marine Science, Oban, Scotland, PA37 1QA	Modelling study using 100 x 8 m turbines operating off the Scottish coast.	Porpoise / Fish	Potential interactions between herring and porpoise with tidal turbines based on populations in Scottish coastal waters.	No avoidance or evasion behaviours were included in the models. Only encounters were modelled, this is not equivalent to impacts or injuries sustained.	The model predicted that in a year of operation, 2% of the herring population and 3.6 to 10.7 % of the porpoise population would encounter a rotating blade.
Copping, A., et al. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/Limitations			
Type of Uncertainty / Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**
Limitations	Collison risk modelling does not account for avoidance behaviour of the mobile features	Fish and mammals	Empirical evidence required to quantify avoidance and acknowledge within collision risk models
Limitations	Modelling requires large density data set (normally two years) which is up-to-date	Birds	Pooling data on bird density, distribution and utilisation – datasets from private sectors made available to inform longer term picture of variability in bird density

Remarks

Observations from case studies have recorded minimal instances of injury or mortality to fish and no instances to marine mammals or birds from tidal turbines. However, the scarcity of examples does not provide enough confidence to move away from the precautionary approach i.e. collision risk modelling informed by baseline surveys to identify density and utilisation by the mobile feature in question. In the case of birds this often requires two-years' worth of seabird data.

Evidence Review Tidal Stream Energy					
Impact Pathway	**Barrier effects to fish and mammal movements or migrations** The physical obstruction of species movements locally (within feeding areas) and regional/global migrations.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
SeaGen Tidal Turbine installation using twin 16 m diameter rotors	Strangford Lough Narrows, Northern Ireland	Marine Mammals / Birds	Shore based survey, passive acoustic monitoring, Aerial survey, harbour seal telemetry, underwater noise monitoring and active sonar.	Sightings of marine mammals in close proximity to the turbine during operation from shore based visual observation, pile-based observation and seal telemetry	The study concluded that no major impacts were detected across the 3 years of post-installation monitoring. There were relatively small scale changes in the behaviour and distribution of seals and harbour porpoises, suggestive of a degree of local avoidance, however this did not prevent transit past the site.
OpenHydro European Marine Energy Centre Series of 6 m open-centre tidal turbines.	Fall of Warness, Orkney, Scotland	Fish	N/A	Video footage taken at the face of the pile-mounted turbine, supplemented by observations of marine mammals and seabirds from land-based observers using binoculars and spotter scopes (Daytime only)	No marine mammals have been observed interacting with the turbines, but seals, porpoises, and small whales are frequently observed transiting through the region, with no barrier effect present.
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study limitations**	**Study Conclusions**
Carol Sparling, Mike Lonergan, Bernie McConnell. 2018. Harbour seals (*Phoca vitulina*) around an operational tidal turbine in Strangford Narrows: No barrier effect but small changes in transit behaviour. Aquatic Conservation Volume 28, Issue 1, Pages 194-204	Strangford Lough Narrows, Northern Ireland	Harbour Seals	Directly discusses barrier effect on harbour seals	Only considers the behaviour of harbour seals, not therefore applicable to all species.	The turbine did not prevent transit of the animals through the channel and therefore did not result in a 'barrier' effect. However, the animals' behaviour did change when the turbine was operating.
Copping, A., et al. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only, however no specific section to focus on barrier effects	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Evidence Review Tidal Stream Energy			
Gaps – Uncertainties/ Limitations			
Type of Uncertainty / Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**
Limitation	Current renewable studies have not focussed specifically on barrier effects. However, recording behaviour, such as avoidance, has led to inference of the potential for barrier effects.	Fish and mammals	Empirical evidence required to quantify avoidance of tidal arrays by fish and mammals
Limitation	There is limited data on migratory pathways of fish and mammals	Fish and mammals	Collection and provision of data on key migratory routes, breeding, spawning and feeding areas for fish and mammals

Remarks

There is scarce evidence available on the potential barrier effects of tidal arrays; however, understanding of the effects can be inferred, to some degree, from those studies carried out on collision. Case examples at Strangford Lough and Fall of Warness indicated that mammals and fish were still transiting through the area. In the USA (Roosevelt Island Tidal Energy (RITE) Project Demonstration; Ocean Renewable Power Company Cobscook Bay Tidal Energy Project), studies of fish behaviour have indicated some general avoidance behaviour but with continued passage around the turbines (see Collison Risk impact pathway).

Most commercially operational tidal devices are either single turbines or comprised of a small array. As arrays increase in size this can be managed through adaptive management.

Evidence Review Tidal Stream Energy					
Impact Pathway	**EMF emissions and their effect on benthic communities and sensitive species** Localised electric and magnetic fields, associated with operational power cables (inter-array and export cables), may could alter behaviour and migration patterns of sensitive species.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
SeaGen Tidal Turbine installation using twin 16 m diameter rotors	Strangford Lough Narrows, Northern Ireland	Marine Mammals	Shore based survey, passive acoustic monitoring, Aerial survey, harbour seal telemetry, underwater noise monitoring and active sonar.	Shore based survey, Passive acoustic monitoring, Aerial survey, harbour seal telemetry, Underwater noise monitoring, active sonar and carcass post mortems.	The study concluded that no major impacts were detected across the 3 years of post-installation monitoring. There were relatively small scale changes in the behaviour and distribution of seals and harbour porpoises, suggestive of a degree of local avoidance. No specific conclusions drawn re: EMF
OpenHydro European Marine Energy Centre Series of 6 m open-centre tidal turbines.	Fall of Warness, Orkney, Scotland	Fish	N/A	Video footage taken at the face of the pile-mounted turbine, supplemented by observations of marine mammals and seabirds from land-based observers using binoculars and spotter scopes (Daytime only)	No marine mammals have been observed interacting with the turbines, but seals, porpoises, and small whales are frequently observed transiting through the region. Fish, began to visit the lee side of the turbine after the first year to graze on vegetation attached to the structure while the blades were not moving. As tidal currents picked up and the turbine began to rotate, the fish appeared to leave the area. In the video analysis to date, no fish have been observed swimming through the turbine while the turbine is rotating and no fish strike mortality has been observed. No specific conclusions drawn re: EMF

Evidence Review Tidal Stream Energy					
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study limitations**	**Study Conclusions**
Gill, A., Bartlett, M., Thomsen, F. (2012). Potential Interactions between Diadromous Fishes of U.K. Conservation Importance and the Electromagnetic Fields and Subsea Noise from Marine Renewable Energy Developments. Journal of Fish Biology, 81(2), 664-695.	Theoretical summary only	Fish	Generally applied to Wind, however cable infrastructure likely to be analogous	Summary only, no evidence presented	Potential for fish to be impacted by EMF, however more likely around a sizeable renewables array if there are multiple interactions between biota and EMF fields in a short amount of time.
Langenfelt, I., Westerberg, H. (2008). Sub-Sea Power Cables And The Migration Behaviour Of The European Eel. Fisheries Management and Ecology, 15(5-6), 369-375.	Baltic Sea	Eels	Specific to eels, may indicate trends to other species.	Limited to eel populations. No details on the behaviour during passage over the cable were available. Possible physiological mechanisms explaining the observed phenomenon are unknown	Observed swimming speed over the ground was corrected for advection by the water current. Eel swimming speed was significantly lower around the cable than both north and south of the cable, potentially attributable to EMF emissions.
Thomsen, F., Gill, A., Kosecka, M., Andersson, M., André, M., Degraer, S., Folegot, T., Gabriel, J.; Judd, A., Neumann, T.; Norro, A., Risch, D., Sigray, P., Wood, D., Wilson, B. (2015). MaRVEN - Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy. Report by Danish Hydraulic Institute (DHI). pp 80.	Summary of multiple measurements at renewables sites in North-West Europe	Measurement of EMF fields	Includes measurements of signatures of UK tidal stream energy assets.	Limited data availability, only two recording drifts were undertaken.	Most energy of the observed tonal signals was between 1 and 2.5 kHz most likely related to the gear ratios of the turning turbines and the operating frequency converter. There was also some energy extending as low as 200 Hz and a broadband signal was observed between 4 and 6 kHz
Cameron Fisher, Ecology and Environment, Inc. Michael Slater, Science Applications International Corp. On behalf of Oregon Wave Energy Trust. 2010. Effects of electromagnetic fields on marine species: A literature review.	Literature Summary	All	Some species considered are applicable to the Welsh biota	N/A literature summary only	Responses to EMF appear species specific, but may experience delayed embryonic development, or disorientation due to the EMF signatures.

Evidence Review Tidal Stream Energy					
Hutchison, Z. L., P. Sigray, H. He, A. B. Gill, J. King, and C. Gibson, 2018. Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-003	Field surveys carried out on three subsea power cables: Two HVDC (Cross Sound Cable (330 MW) and Neptune Cables (660 MW)); one AC cable (sea2shore cable (30 MW)).	Lobster and skate	Inferences to similar species found in Welsh waters. Study analogous to any development with HVDC and HVAC subsea cables.	Limited to two species	Clear behavioural changes noted in both species movement and distribution around subsea cable. No evidence of barrier to movements across subsea cable.
Copping, A., *et al*. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/ Limitations

Type of Uncertainty / Limitation	Description	Key Receptors Affected	Recommendations to Address the Limitation or Uncertainty
Uncertainty	The potential to affect features is likely related to the power ratings from the array and through the cable(s). Hence, comparatively small tidal arrays such as test sites, are less likely to have a significant effect on features	All	Highlighting the findings from studies such as Hutchison *et al*. (2018) to regulators and stakeholders may reduce requirement for assessing potential impacts from EMF for small scale tidal developments. Further work required to understand when potential effects from EMF may become significant to features i.e. size of array/power rating
Limitation	Data is limited to a relatively small number of species and responses appear species specific, i.e. responses of different fish cannot be extrapolated to local fauna.	Fish / Marine mammals	Further studies on responses of sensitive marine features to EMF

Remarks

Evidence, though scarce, indicates that measurable effects from EMF can occur on sensitive fish species (e.g. elasmobranchs) and benthic invertebrates. Work by Hutchison *et al.* (2018) indicated that EMF from HVDC cables (≥300 MW) resulted in a behavioural response by elasmobranchs and crustaceans; however, the response was considered minor and did not represent a barrier to movement.

Further evidence is required to understand if large developments and multiple subsea cables with high power ratings have the potential to result in greater effects, such as barriers to movement, on marine species.

Evidence Review Tidal Stream Energy					
Impact Pathway	**Effects of underwater noise on mammals and fish during operation** The potential effects on mammals and fish from operational noise of tidal arrays may manifest as auditory masking, disturbance and/or barrier effects. Although noise generated would be less than construction activities such as piling, the increase in noise will be long-term and continuous.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
SeaGen Tidal Turbine installation using twin 16 m diameter rotors	Strangford Lough Narrows, Northern Ireland	Marine mammals / birds	Shore based survey, passive acoustic monitoring, Aerial survey, harbour seal telemetry, underwater noise monitoring and active sonar.	Measurement of operational noise, modelling propagation and prediction of likely impacts on marine mammals. Sightings of marine mammals in close proximity to the turbine during operation from shore based visual observation, pile-based observation and seal telemetry	The study concluded that no major impacts were detected across the 3 years of post-installation monitoring. Noise from an operating SeaGen are below levels expected to cause auditory injury. When considering cumulative noise exposure, the zones predicted for potential auditory injury are small and residence times within these would need to be high for any marine mammals to be at risk from injury. Seals and harbour porpoises, but animals are regularly sighted within the range of predicted behavioural avoidance as a result of noise, however residence times are below those required to cause damage.
Ocean Renewable Power Company Cobscook Bay Tidal Energy Project Three cross-axis turbine generator units in 26 m of water.	Cobscook Bay, Maine, USA	Fish	N/A	Drifting noise measurement system (DNMS)	Ambient and operational noise associated with the turbine will be detected by some marine animals that occur near the project site. However, based on the noise levels detected during its investigation, behavioural responses and physical harm to marine organisms are unlikely.
Minesto Deep Green Holyhead Deep Project (EIA)	Holyhead Deep, Irish Sea, NW Wales.	Marine mammals/ fish	Underwater noise measurements and modelling of noise generated by three tidal array units (DGU)	N/A	Noise emissions predicted as highly localised and insufficiently loud to realistically induce injury to any marine mammal species. Any behavioural changes unlikely to be detectable against natural variation.

Evidence Review Tidal Stream Energy					
					The potential effects of operational noise on mammals were accepted as not significant for the Minesto EIA. The effects of operational underwater noise on fish were scoped out of consideration for this project
Available Evidence Base					
Key scientific literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study Limitations**	**Study Conclusions**
Halvorsen, M.; Carlson, T.; Copping, A. (2011). Effects Of Tidal Turbine Noise On Fish Hearing And Tissues. Report by Pacific Northwest National Laboratory (PNNL) and Snohomish County PUD. pp 48.	Laboratory Study	Fish (Chinook Salmon)	Useful indicator of effects of tidal turbines	Only simulates a 6 m diameter OpenHydro turbine on one species	Experimental results indicate that non-lethal, low levels of tissue damage may have occurred but that there were no effects of noise exposure on the auditory systems of the test fish.
Thomsen, F., Gill, A., Kosecka, M., Andersson, M., André, M., Degraer, S., Folegot, T., Gabriel, J., Judd, A., Neumann, T.; Norro, A., Risch, D., Sigray, P., Wood, D., Wilson, B. (2015). MaRVEN - Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy. Report by Danish Hydraulic Institute (DHI). pp 80.	Summary of multiple measurements at renewables sites in North-West Europe	Measurement of sound fields	Includes measurements of noise from two of UK tidal stream energy assets.	Limited data availability, only two recording drifts were undertaken	Ambient vs operational turbines showed a 10 to 15 dB difference in sound levels in the dominant sound bands (1 – 2.5 kHz) at a median distance of 282 m. At a distance of about 500 – 600 m, sound levels emitted by the turbines may be expected to be equal to or below ambient sound levels
Copping, A., *et al*. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/ Limitations			
Type of Uncertainty/ Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address Limitations and Uncertainties**
Uncertainty	Too many uncertainties around potential behavioural effects from underwater noise	All	Further studies to gather empirical evidence on behaviour around tidal arrays
Limitation	Evidence is limited by the varied scope and nature of the developments coupled with the differing physical environment	All	Noise modelling required based on physical site-specific data and proposal specifications.

Evidence Review	Tidal Stream Energy

Remarks

The potential for acute effects (injury and mortality) on mammals, fish and diving birds during operation is unlikely. However, the potential for chronic effects such as auditory masking and disturbance is not well understood.

Scoping opinions received in 2018 to proposed tidal arrays in Wales (i.e. Enlli Tidal Energy and TBG projects) have requested consideration of operational noise effects on fish, mammals and, in the case of TBG, diving birds. Underwater noise modelling in conjunction with current and accepted scientific literature on noise thresholds for various features are required.

Considering the varied scope of potential tidal arrays and the different technologies emerging there is no evidence available that could be consistently applied with confidence in the potential effects. Hence, allowances for the multitude of variables can only be addressed through predictive modelling to understand noise generation and propagation.

Confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

F.2 Wave Energy

Evidence Review	Wave Energy
Impact Pathway	**Indirect effects on marine features as a consequence of changes to coastal processes** Operation of the wave energy device(s) will result in the removal of energy from the hydrodynamic system. This pathway will change wave climate with resultant changes on local currents and potentially sediment transport. Should changes to sediment transport regime occur there is potential to effect morphology of seabed and coastal features. Changes to wave climate, flow direction and velocity also have the potential to effect water quality such as through changes to suspended sediment concentrations. Indirectly, the changes in hydrodynamics and sediment transport can lead to changes in community composition and habitat type.

Available Evidence Base

Key Scientific Literature

Reference	Location	Key receptors	Applicability	Study Limitations	Study Conclusions
Abanades, J., Greaves, D., Iglesias, G. (2014). Wave Farm Impact on the Beach Profile: A Case Study. Coastal Engineering, 86, 36-44.	Perranporth Beach, UK (Modelled)	Beach Profile	Specific to Perranporth beach morphological dynamics, however conclusions can be read across to Welsh schemes	Modelled only, with no field measurement validation. Location specific results.	The wave farm reduced wave action at the coast, reducing erosion of the beach face. Concludes that wave farms have the potential to be used as part of coastal defence schemes.
Iglesias, G., Carballo, R. (2014). Wave Farm Impact: The Role of Farm-to-Coast Distance. Renewable Energy, 69, 375-385.	Galicia, Spain (Modelled)	Change in wave dynamics at coastline	Specific to location and to one infrastructure type, however some read across to Welsh schemes.	Limited to varying one variable (farm-coast distance) and assessment of that impact. Does not assess the impact in changes to the wave regime on coastline.	Increasing the distance to coast changes the location of the point of maximum impact; however, it does not necessarily reduce the degree of impact.
PMSS Ltd (2007). Wave Dragon Pre-Commercial Wave Energy Device, Environmental Statement Volume 1: Non-Technical Summary. Report by TÜV SÜD PMSS and Wave Dragon ApS. pp 23.	Pembrokeshire, Wales (Assessment)	Environmental Impact Assessment	Applicable to overtopping infrastructure only, no modelling / field study results to discuss. Desk based study only.	Assessment only, no modelling / data to back up conclusions.	Concluded that moderate reduction in wave energy close to site; however, no noticeable impact at shoreline. Overall, no significant impacts identified with the exception of cable installation disturbing seabed habitat.
Chang, G., Magalen, J., Jones, C., and Roberts, J., 2014. Investigation of Wave Energy Converter Effects on the Nearshore Environment: A Month-Long Study in Monterey Bay, CA. Sandia National Laboratories	Monterey Bay, CA (Modelled)	Wave Height	Applicable to arrays of floating two-body heaving converter and floating oscillating water column only.	Limited to two types of wave energy installation. Specific to location, and single month of data to provide wave heights to the model.	The wave heights were reduced by up to 15% downstream of the arrays.

Evidence Review Wave Energy					
Copping, A., *et al*. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/ Limitations

Type of Uncertainty / Limitation	Description	Key Receptors Affected	Recommendations to Address the Limitation or Uncertainty
Uncertainty	Irrespective of the pre-existing data and evidence there will always be uncertainties of the potential effect on physical processes which can only be predicted through modelling	Physical processes and seabed morphology	Modelling carried out based on physical site-specific data and proposal specifications.
Limitation	There is limited physical data collected from installed wave energy arrays that can be used to validate models at either small or large scales.	Sediment Transport / Hydrodynamics	Collection of physical data during operation of the wave energy device will provide a mechanism for validation of predicted changes and hence allow refinement of models. This will increase confidence in predictions.
Limitation	There are no operational schemes that have reported on this pathway.	All	Ensuring that the effects on wave climate, flows and sediment transport are monitored during operation and the findings communicated.

Remarks

As an emerging technology there is scarce empirical evidence of the potential effects from this pathway. Consideration of the multitude of variables can only be addressed through predictive modelling (hydrodynamic and sediment transport) to assess the potential effects from changes on physical processes.

Confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

Infrastructure associated with the installations (foundations / anchoring points) may change flows in the immediate area of the wave energy devices; however, resultant spatial extent of these changes (e.g. on sediment transport) is likely to be highly localised.

Evidence Review Wave Energy					
Impact Pathway Collision Risk	**Collision of mobile marine features resulting in injury or mortality** The presence of wave energy devices has the potential to result in injury or mortality to marine mammals and fish				
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key receptors**	**Applicability**	**Study Limitations**	**Study Conclusions**
ABP Marine Environmental Research Ltd (2010). Collision Risk of Fish with Wave and Tidal Devices. Report by ABP Marine Environmental Research Ltd (ABPmer), RPS group, and Welsh Assembly Government. pp 106.	Overview of research	Fish	Summary of potential fish interactions with wave devices	Lack of direct observation studies	Wave devices generally all pose a low risk of collision damage and confidence in this assessment is high.
Riefolo, Luigia & Lanfredi, Caterina & Azzellino, Arianna & Vicinanza, Diego. (2015). Environmental Impact Assessment Of Wave Energy Converters: A Review.	Overview of EIA conclusions.	All	Summary of EIA undertaken for Wave energy infrastructure.	Lack of data to support conclusions.	Impacts on marine life considered to be low. Collision risk influenced by awareness of the presence of surface structures.
Copping, A., *et al*. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines
Gaps – Uncertainties/ Limitations					
Type of Uncertainty / Limitation	**Description**		**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**	
Uncertainty	Lack of empirical evidence		Fish and mammals	Field studies required to assess likelihood of collision risk.	
Remarks The limited evidence on the potential collision risk from wave energy devices suggests that collision impacts to marine mammals or fish are low risk. As a surface water technology rather than located mid-water or on the seabed (i.e. tidal turbines) it is less likely to pose a risk to collision as compared with tidal arrays. Empirical evidence required from monitoring studies to provide greater confidence in assessment predictions.					

Evidence Review Wave Energy					
Impact Pathway Barrier Effects	**Barrier effects to fish and mammal movements or migrations** The physical obstruction of species movements locally (within feeding areas) and regional/global migrations.				
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key Receptors**	**Applicability**	**Study Limitations**	**Study Conclusions**
Copping, A., et al. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only, however no specific section to focus on barrier effects	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines
Gaps – Uncertainties and Limitations					
Type of Uncertainty / Limitation	**Description**		**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**	
Limitation	Current renewable studies have not focussed specifically on barrier effects, however in recording the behaviour of marine organisms, the potential for barrier effects can be inferred.		Fish and mammals	Empirical evidence required to quantify avoidance of wave energy devices by fish and mammals	
Remarks There is scarce evidence available on the potential barrier effects of wave energy devices; however, understanding of the effects can be inferred from those studies on collision risk. As a surface water technology, rather than located mid-water or on the seabed (i.e. tidal turbines), it is less likely to pose a risk to movements of fish or marine mammals as compared with tidal arrays. Empirical evidence is required from monitoring studies to provide greater confidence in assessment predictions.					

Evidence Review Wave Energy					
Impact Pathway	**EMF emissions and their effect on benthic communities and sensitive species** Localised electric and magnetic fields, associated with operational power cables (inter-array and export cables), could alter behaviour and migration patterns of sensitive species.				
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key Receptors**	**Applicability**	**Study Limitations**	**Study Conclusions**
Gill, A., Bartlett, M., Thomsen, F. (2012). Potential Interactions between Diadromous Fishes of U.K. Conservation Importance and the Electromagnetic Fields and Subsea Noise from Marine Renewable Energy Developments. Journal of Fish Biology, 81(2), 664-695.	Theoretical summary only	Fish	Generally applied to wind farms arrays; however, cable infrastructure likely to be analogous	Summary only, no evidence presented	Potential for fish to be impacted by EMF. Effects more likely around a sizeable renewables array if there are multiple interactions between biota and EMF fields in a short amount of time.
Thomsen, F., Gill, A., Kosecka, M., Andersson, M., André, M., Degraer, S., Folegot, T., Gabriel, J.; Judd, A., Neumann, T.; Norro, A., Risch, D., Sigray, P., Wood, D., Wilson, B. (2015). MaRVEN - Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy. Report by Danish Hydraulic Institute (DHI). pp 80.	Summary of multiple measurements at renewables sites in North-West Europe	Measurements of EMF fields	Includes measurements of signatures of UK tidal stream energy assets, cable infrastructure likely to be applicable to wave	Limited data availability, only two recording drifts were undertaken.	Most energy of the observed tonal signals was between 1 and 2.5 kHz most likely related to the gear ratios of the turning turbines and the operating frequency converter. There was also some energy extending as low as 200 Hz and a broadband signal was observed between 4 and 6 kHz
Cameron Fisher, Ecology and Environment, Inc. Michael Slater, Science Applications International Corp. On behalf of Oregon Wave Energy Trust. 2010. Effects of electromagnetic fields on marine species: A literature review.	Literature Summary	All	Some species considered are applicable to the Welsh biota	N/A literature summary only	Responses to EMF appear species specific, but may experience delayed embryonic development, or disorientation due to the EMF signatures.
Hutchison, Z. L., P. Sigray, H. He, A. B. Gill, J. King, and C. Gibson, 2018. Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables.	Field surveys carried out on three subsea power cables: Two HVDC (Cross Sound Cable (330 MW) and Neptune Cables (660 MW)); one AC cable (sea2shore cable (30 MW)).	Lobster and skate	Inferences to similar species found in Welsh waters. Study analogous to any development with HVDC and HVAC subsea cables.	Limited to two species	Clear behavioural changes noted in both species movement and distribution around subsea cable. No evidence of barrier to movements across subsea cable.

Evidence Review Wave Energy					
Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-003					
Langenfelt, I., Westerberg, H. (2008). Subsea Power Cables and the Migration Behaviour of the European Eel. Fisheries Management and Ecology, 15(5-6), 369-375.	Baltic Sea	Eels	Specific to eels, may indicate trends to other species.	Limited to eel populations. No details on the behaviour during passage over the cable were available. Possible physiological mechanisms explaining the observed phenomenon are unknown	Observed swimming speed over the ground was corrected for advection by the water current. Eel swimming speed was significantly lower around the cable than both north and south of the cable, potentially attributable to EMF emissions.
Copping, A., *et al*. 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All.	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only, no evidence found of significant environmental effects from tidal turbines

Gaps – Uncertainties/ Limitations			
Type of Uncertainty / Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**
Uncertainty	The potential to affect features is likely related to the power ratings from the array and through the cable(s). Hence, comparatively small tidal arrays such as test sites, are less likely to have a significant effect on features	All	Highlighting the findings from studies such as Hutchison *et al.* (2018) to regulators and stakeholders may reduce requirement for assessing potential impacts from EMF for small scale tidal developments. Further work required to understand when potential effects from EMF may become significant to features i.e. size of array/power rating
Limitation	Data is limited to a relatively small number of species and responses appear species specific, i.e. responses of different fish cannot be extrapolated to local fauna.	Fish / Marine mammals	Further studies on responses of sensitive marine features to EMF

Remarks

Evidence, though scarce, indicates that measurable effects from EMF can occur on sensitive fish species (e.g. elasmobranchs) and benthic invertebrates. Work by Hutchison *et al.* (2018) indicated that EMF from HVDC cables (≥300 MW) resulted in a behavioural response to elasmobranchs and crustaceans; however, the response was considered minor and did not represent a barrier to movement.

Further evidence is required to understand if large developments and multiple subsea cables with high power ratings have the potential to result in greater effects, such as barriers to movement, on marine species.

Evidence Review Wave Energy					
Impact Pathway	**Effects of underwater noise on mammals and fish during operation** The potential effects on mammals and fish from operational noise of tidal arrays may manifest as auditory masking, disturbance and/or barrier effects. Although noise generated would be less than construction activities such as piling, the increase in noise will be long-term and continuous.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
The Lysekil research site	Lysekil, Sweden	Fish and Marine Mammals	N/A	Noise Detection	Many marine animals will be able to detect the noise from the operating Wave Energy Converter, but the noise was not sufficient to cause fish to change their behaviour or be physically injured at the site and unlikely to cause injury to marine mammals.
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key Receptors**	**Applicability**	**Study Limitations**	**Study Conclusions**
Thomsen, F., Gill, A., Kosecka, M., Andersson, M., André, M., Degraer, S., Folegot, T., Gabriel, J., Judd, A., Neumann, T., Norro, A., Risch, D., Sigray, P., Wood, D., Wilson, B., 2015. MaRVEN - Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy. Report by Danish Hydraulic Institute (DHI). pp 80.	Summary of multiple measurements at renewables sites in North-West Europe	Measurement of sound fields	Includes measurements of noise from two wave energy assets.	The maximum sound level in terms of particle motion remains to be described for any wave energy device. Future measurements should be undertaken under a variety of weather and wave conditions, since variable wave heights may change the interactions and potential sound generation.	Levels of sound pressure were below fish hearing threshold at a distance of 23 m for wave heights up to 2 m (Sweden). No predicted noise effects from the wave device on receptor species at a distance of 400 m or more (Scotland).
Tougaard, J., 2015. Underwater Noise from a Wave Energy Converter Is Unlikely to Affect Marine Mammals. PLOS ONE 10(7): e0132391.	Danish North Sea Coast	Marine Mammals	Applicable to Wavestar wave energy converters	The results may not be directly transferable to other wave converter designs.	Noise levels from the operating wave converter were so low that they would barely be audible to marine mammals and the likelihood of negative impact from the noise appears minimal. Increased noise levels during start up considered unlikely to cause impacts to marine mammals.

Evidence Review Wave Energy					
Copping, A. *et al*., 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World.	Worldwide summary	All	Summarises evidence from worldwide evidence base	N/A - Evidence summary only	N/A - Evidence summary only. Information available suggests marine mammals are unlikely to be seriously injured or killed by operation of wave energy devices
Gaps – Uncertainties/ Limitations					
Type of Uncertainty / Limitation	**Description**		**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**	
Uncertainty	Too many uncertainties around potential behavioural effects from underwater noise		All	Further studies to gather empirical evidence on fish and mammal behaviour around wave energy devices	
Limitation	Evidence is limited by the varied scope and nature of the developments coupled with the differing physical environments		All	Noise modelling required based on physical site-specific data and proposal specifications	

Remarks

Evidence, though scarce, suggests that the effects of operational underwater noise on fish and mammals would be minimal.

However, considering the varied scope of potential wave energy devices and the different technologies emerging, at this time there is no evidence available that could be consistently and confidently applied to understand the potential effects from underwater noise. Hence, allowances for the multitude of variables can only be addressed through predictive modelling to understand noise generation and propagation.

Confidence in the models can be increased through monitoring programmes (post-consent, post-construction) used to validate results. As evidence becomes available of validated modelling predictions, these should be acknowledged by developers and regulators to inform the development of models and future modelling studies.

F.3 Shellfish Aquaculture

Evidence Review	Shellfish Aquaculture				
Impact Pathway	**Introduction of Invasive Non-Native Species (INNS)** Introduction and spread of INNS can occur through the transfer of aquaculture stock (e.g. the movement of shellfish spat/seed between the area of collection to the on-growing site). Depending on the INNS introduced and the characteristics of the site, the INNS can become established.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Receptors**	**Baseline**	**Monitoring**	**Findings**
Bangor Mussel Producers Association, (2008) . Code of good practice for mussel seed movements. Version 1: July 2008 Available online: https://www.nw-ifca.gov.uk/app/uploads/Code-of-Good-Practice-seed-mussel-movement.pdf The Code provides a working protocol that enables the shellfish industry to safely continue the practice of importing mussel seed from areas outside the Menai Strait, without contributing to the spread of INNS.	North Wales	Benthic habitats and associated communities Existing aquaculture production companies	N/A	N/A	The CoGP, was drawn up by an inter-agency group in 2008. The Code is applicable to both ship-borne and road movements of mussel seed into the Menai Strait to prevent the accidental introduction of INNS not currently occurring in North Wales. The Code includes monitoring of mussel lays post seed movement and eradication measures in the event that an INNS is discovered in mussel lays. The CoGP has since been made a condition of issuing shellfish movement licences (which are only available to vessels harvesting seed mussel for deposit on registered shellfish farms) and a licence will only be issued subject to scientific advice that the dredging operation would not be incompatible with wider environmental considerations (Welsh Government, 2015).

Gaps – Uncertainties/Limitations			
Type of Uncertainty/ Limitation	**Description**	**Key Receptors Affected**	**Recommendations to Address the Limitation or Uncertainty**
Limitation	Identification of a INNS or recognition of a new INNS to Welsh waters	Benthic communities	Ensuring industry are aware of and regularly updated on the priority marine INNS for Wales and those species on the Welsh surveillance list

Remarks

The issue of INNS is well recognised within the UK with a number of mechanisms, across many sectors, implemented to prevent the introduction and spread of INNS. Within England and Wales the following legislative requirements relating to the prevention and spread of finfish and shellfish disease and INNS apply to all aquaculture developments:

- The requirement for all Aquaculture Production Businesses (APBs) to be authorised by the Fish Health Inspectorate (FHI), Cefas to operate and import livestock under the Aquatic Animal Health (England & Wales) Regulations 2009.
- Requirement for aquaculture operators intending to undertake the introduction of an alien species or the translocation of a locally absent species to apply for a permit from FHI under The Alien and Locally Absent Species in Aquaculture (England & Wales) Regulations 2011 (where not exempted in Annex IV).

Evidence Review Shellfish Aquaculture
The CoGP (see above), produced by the Welsh shellfish industry in 2008, indicates a well-developed understanding of the potential issues of INNS and how to reduce the risk within this type of aquaculture. The CoGP also makes provision for unfamiliar species, these potentially representing INNS, and the requirement for continual vigilance, acknowledging that the Code may need to be adapted as understanding of marine INNS increases. Recent studies have identified species that are considered priority marine INNS (Marine Invasive Non-native Species: Priority Monitoring and Surveillance List for Wales. Published January 2018. Available online: https://beta.gov.wales/sites/default/files/publications/2018-02/invasive-aquatic-species-priority-marine-species.pdf) in welsh waters. Ensuring regular communication to the Welsh aquaculture industry will allow producers and developers to adapt the Code, if required, and be informed on the latest understanding of marine INNS. Marine biosecurity planning guidance covering Wales and England (Cook *et al.*, 2014), provides general guidance for commercial and recreational users towards controlling the introduction and spread of marine INNS. An inherent limitation to reducing the potential of this impact in any sector is the recognition of an INNS. Some species are cryptic in appearance e.g. *Didemnum vexillum* and not easily differentiated from congeneric species while others may be unfamiliar if new to Welsh waters. The CoGP also makes provision for 'pest identification cards' to allow workers to identify key marine INNS. Updating these cards to align with those on the Welsh priority marine INNS will continue to reduce the risk from inadvertent introduction of marine INNS in shellfish aquaculture

F.4 Finfish Aquaculture

Evidence Review	Finfish Aquaculture				
Impact Pathway	**Discharges (particulate waste, chemicals) and impacts on water and sediment quality and benthic habitats** Operation of fish farms results in discharges including solid wastes (i.e. uneaten food and faeces from cages), dissolved nutrient inputs and medicines/chemicals (for treatment of parasites, antimicrobials and heavy metals). Fish farm organic waste accumulating on the seabed can significantly degrade communities of benthic animals beneath or near farms whilst significant enrichment of lochs and regional seas by fish farm nutrients could lead to enhanced growth of phytoplankton, with impacts on marine communities and water quality. Synthetic chemicals (including antibiotics) used to treat lice infestation or fish diseases, to prevent fouling of farm structure, or as dietary supplements, may impact on other organisms.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Features**	**Baseline**	**Monitoring**	**Findings**
The Code of Good Practice (CoGP) for Scottish Finfish Aquaculture	Scotland	Multiple	N/A	N/A	Chapter 4 of the CoGP relates to fish farm operations in seawater lochs and sections include fish health and biosecurity; managing and protecting the environment and feed and feeding
Key Scientific Literature					
Reference	**Location**	**Key Features**	**Applicability**	**Study Limitations**	**Study Conclusions**
The Scottish Association of Marine Science (SAMS), 2018. Review of the environmental impacts of salmon farming in Scotland. Issue 01, January 2018 (and references therein).	Scotland	Water quality and plankton communities	Comprehensive review of the environmental impacts of salmon farming in Scotland, the scale of the impacts and approaches to mitigating the impacts.	Literature review	Increased (but not harmful) concentrations of ammonia and phosphate can be observed within a few tens of metres of farms. Modelling predictions showed increased nutrients in lochs (and maybe in coastal waters), arising from salmon farms; however, there is no evidence of increased phytoplankton growth or production due to these nutrients. Data enabling assessment of changes in plankton communities over time are generally limited. Modelling suggested that organic waste from farms could add to the risk of deoxygenation in poorly flushed lochs where water is trapped behind sills. Opportunistic green algae growth can occur near farms, although this is not significant at the waterbody level (i.e. at sealoch scale).

Evidence Review	Finfish Aquaculture				
	As above	Sediment quality and benthic habitats	As above	Literature review	In low dispersion environments with slow currents and limited wave action, sinking particulate waste results in physical smothering, low oxygen levels and reduced biodiversity of the seabed community within the farm 'footprint'. The recovery rate of benthic communities during fallowing varies with local conditions and full recovery may take longer than the two years typically allowed. The licensing process aims to avoid impacts to protected habitats but there is some evidence of impact on maerl. In Scotland, benthic monitoring near farms is not sufficiently synthesised to enable tracking of long term changes.
	As above	Pelagic and benthic communities	As above	Literature review	The synthetic chemicals used in aquaculture are biocides and hence their persistence in the environment may affect non-target organisms (i.e. beyond the parasite/disease target). There is a lack of knowledge about the diffuse far-field effect of these chemicals on benthic and pelagic ecosystem components

Gaps – Uncertainties/ Limitations			
Type of Uncertainty/ Limitation	**Description**	**Key Features**	**Recommendations to Address Limitation or Uncertainty**
Uncertainty	Some uncertainty on degree of indirect impacts from fish farming	All	Further evidence most likely to arise from Scotland via ongoing and future monitoring data and research

Remarks

Evidence on potential impact pathways on the environment from finfish mariculture is well researched in Scotland. As this type of aquaculture develops in Welsh waters the conclusions of peer-reviewed research and ongoing monitoring studies should be acknowledged. Gaps identified in the evidence base have been highlighted in Scottish waters and recognition of these will provide greater understanding to developers of the potential hurdles to consenting.

Existing Scottish legislation and guidance prevents or reduces operational impacts of finfish farming and these will assist Welsh development of this industry. Lessons learned from recent evidence reviews of fish health and environmental challenges in Scotland, and development of new regulatory frameworks (e.g. SEPA's draft finfish aquaculture sector plan) and modelling tools to understand the impact of fishfarm discharges on the seabed and assist with site selection (NewDEPOMOD) will be particularly important.

Evidence Review	Finfish Aquaculture				
Impact Pathway	**Transfers of pathogens and parasites to wild fish populations** Transfer of disease (e.g. Infectious Salmon Anaemia) and parasites (e.g. sealice) from farmed stock to wild fish populations. The presence of large numbers of fish on a farm provides a favourable habitat for the growth and spread of pathogen and parasite populations. Depending on the mode of infection, water currents may spread pathogens between farms and potentially between wild and farmed populations.				
Case Examples					
Scheme/ Initiative	**Summary of Scheme**				
	Geographic Location	**Features**	**Baseline**	**Monitoring**	**Findings**
The Code of Good Practice (CoGP) for Scottish Finfish Aquaculture	Scotland	Multiple	N/A	N/A	Chapter 4 of the CoGP relates to fish farm operations in seawater lochs and sections include fish health and biosecurity.
Key Scientific Literature					
Reference	**Location**	**Key Features**	**Applicability**	**Study Limitations**	**Study Conclusions**
The Scottish Association of Marine Science (SAMS), 2018. Review of the environmental impacts of salmon farming in Scotland. Issue 01, January 2018 (and references therein).	Scotland	Wild fish (salmonids)	Comprehensive review of the environmental impacts of salmon farming in Scotland, the scale of the impacts and approaches to mitigating the impacts.	Literature review	Increased abundance of sealice on farmed salmon may correlate with increased numbers of lice on wild salmon (in the same water body), although conclusive evidence for damage at the population level is hard to find in Scotland. Some evidence that diseases are transmitted between farmed and wild fish by direct infection, by escapees or by infection from wild to farmed fish.
Gaps – Uncertainties/ Limitations					
Type of Uncertainty/ Limitation	**Description**		**Key Features**	**Recommendations to Address Limitation or Uncertainty**	
Uncertainty	Efficacy of management and regulatory regime for sealice		Wild fish (salmonids)	Further evidence most likely to arise from Scotland via ongoing and future monitoring data and research	

Remarks

There is evidence to suggest that sealice are becoming increasingly resistant to chemical treatments which may also correlate to increases in sealice observed on wild fish.

Evidence on potential impact pathways on the environment from finfish mariculture is well researched in Scotland. As this type of aquaculture develops in Welsh waters the conclusions of peer-reviewed research and ongoing monitoring studies should be acknowledged. Gaps identified in the evidence base have been highlighted in Scottish waters and recognition of these will provide greater understanding to developers of the potential hurdles to consenting.

Existing Scottish legislation and guidance prevents or reduces operational impacts of finfish farming and these will assist Welsh development of this industry. Lessons learned from recent evidence reviews of fish health and environmental challenges in Scotland will be particularly important.

Evidence Review	Finfish Aquaculture				
Impact Pathway	**Genetic interaction between escapees and wild fish populations** Farmed fish escapees may interbreed with wild fish populations, harming the gene pool of wild salmonid stocks. Such an impact could affect the long-term health of wild salmonids.				
Available Evidence Base					
Key Scientific Literature					
Reference	**Location**	**Key Features**	**Applicability**	**Study Limitations**	**Study Conclusions**
The Scottish Association of Marine Science (SAMS), 2018. Review of the environmental impacts of salmon farming in Scotland. Issue 01, January 2018 (and references therein).	Scotland	Wild fish (salmonids)	Comprehensive review of the environmental impacts of salmon farming in Scotland and the scale of the impacts	Literature review	There is limited information on the extent of genetic mixing between farmed and wild salmonid populations in Scotland. Most evidence about the genetic impacts come from Norway, where impacts have been shown to include changes in smolt maturation age and size in wild salmon. Such changes could reduce the ability of wild populations to adapt to changes in environmental conditions.
Gaps – Uncertainties/ Limitations					
Type of Uncertainty/ Limitation	**Description**		**Key Features**	**Recommendations to Address Limitation or Uncertainty**	
Uncertainty	Lack of information/data on extent of genetic interchange between farmed and wild salmon in Scotland		Wild fish (salmonids)	Further evidence most likely to arise from Scotland via ongoing and future monitoring data and research	

Remarks

In Norway, gene flow from escapees to wild salmon has been shown to change smolt maturation age and size which may affect the populations adaptiveness to conditions in their native rivers. However, there is little information regarding the extent of such genetic mixing in Scottish salmon (SAMS, 2018).

Evidence on potential impact pathways on the environment from finfish mariculture is well researched in Scotland. As this type of aquaculture develops in Welsh waters the conclusions of peer-reviewed research and ongoing monitoring studies should be acknowledged. Gaps identified in the evidence base have been highlighted in Scottish waters and recognition of these will provide greater understanding to developers of the potential hurdles to consenting.

Existing Scottish legislation and guidance prevents or reduces operational impacts of finfish farming and these will assist Welsh development of this industry. Lessons learned from recent evidence reviews of fish health and environmental challenges in Scotland will be particularly important.

<table>
<tr><th colspan="6">Evidence Review Finfish Aquaculture</th></tr>
<tr><td>Impact Pathway</td><td colspan="5">Management of predators (seals primarily)

Disturbance to marine mammals and birds from non-lethal deterrents (e.g. netting, acoustic methods) used for management of predators. Potential impacts may include entanglement in netting or behavioural changes caused by use of underwater acoustic deterrent devices (ADDs) on seals or cetaceans.</td></tr>
<tr><td colspan="6">Case Examples</td></tr>
<tr><td rowspan="2">Scheme/ Initiative</td><td colspan="5">Summary of Scheme</td></tr>
<tr><td>Geographic Location</td><td>Features</td><td>Baseline</td><td>Monitoring</td><td>Findings</td></tr>
<tr><td>The Code of Good Practice (CoGP) for Scottish Finfish Aquaculture</td><td>Scotland</td><td>Multiple</td><td>N/A</td><td>N/A</td><td>Chapter 4 of the CoGP relates to fish farm operations in seawater lochs. Sections include predator control.</td></tr>
<tr><td colspan="6">Available Evidence Base</td></tr>
<tr><td colspan="6">Key Scientific Literature</td></tr>
<tr><td>Reference</td><td>Location</td><td>Key Features</td><td>Applicability</td><td>Study Limitations</td><td>Study Conclusions</td></tr>
<tr><td>The Scottish Association of Marine Science (SAMS), 2018. Review of the environmental impacts of salmon farming in Scotland. Issue 01, January 2018 (and references therein).</td><td>Scotland</td><td>Marine mammals (seals, cetaceans) and birds</td><td>Comprehensive review of the environmental impacts of salmon farming in Scotland. Relevant to Welsh waters.</td><td>Literature review</td><td>Mortality risk from entanglement for birds and marine mammals is poorly studied.

There is limited evidence relating to the efficacy of ADDs</td></tr>
<tr><td colspan="6">Gaps – Uncertainties/ Limitations</td></tr>
<tr><td>Type of Uncertainty/ Limitation</td><td colspan="2">Description</td><td>Key Features</td><td colspan="2">Recommendations to Address Limitation or Uncertainty</td></tr>
<tr><td>Limitation</td><td colspan="2">Lack of evidence of mortality risk from entanglement in anti-predator netting</td><td>Marine mammals and birds</td><td colspan="2">Further evidence most likely to arise from Scotland via ongoing and future monitoring data and research</td></tr>
<tr><td>Limitation</td><td colspan="2">There is limited evidence relating to the efficacy of ADDs</td><td>Marine mammals (particularly cetaceans)</td><td colspan="2">Further evidence most likely to arise from Scotland via monitoring data and research and/or other sectors which use ADD e.g. offshore renewables</td></tr>
<tr><td colspan="6">Remarks
Better reporting of ADD usage and increased understanding of ADD efficacy and impact could help assess and manage the trade-off between predator deterrence (i.e. seals) and noise pollution effects, including on sensitive marine mammals (e.g. cetaceans).

Evidence on potential impact pathways on the environment from finfish mariculture is well researched in Scotland. As this type of aquaculture develops in Welsh waters the conclusions of peer-reviewed research and ongoing monitoring studies should be acknowledged. Gaps identified in the evidence base have been highlighted in Scottish waters and recognition of these will provide greater understanding to developers of the potential hurdles to consenting.

Existing Scottish legislation and guidance prevents or reduces operational impacts of finfish farming and these will assist Welsh development of this industry. Lessons learned from recent evidence reviews of fish health and environmental challenges in Scotland will be particularly important.</td></tr>
</table>

G Marine Spatial Planning Tools

Marine planning is an important process for supporting the sustainable development of Welsh seas. There are a range of marine planning tools available to assist developers and regulators at various stages of the planning process. This appendix provides an overview of the tools available for marine planning before providing examples of several recent tools used for the assessment of focus activities. The key focus was on identifying tools which would improve access to data and its usability within marine planning.

Planning tools can be split into five broad categories, in line with current Marine Spatial Planning (MSP) literature (Ehler and Douvere, 2009, Stamoulis and Delevaux, 2015):

- Data Management;
- Data Processing;
- Data Analysis/ Assessment
- Decision Support; and
- Stakeholder Engagement.

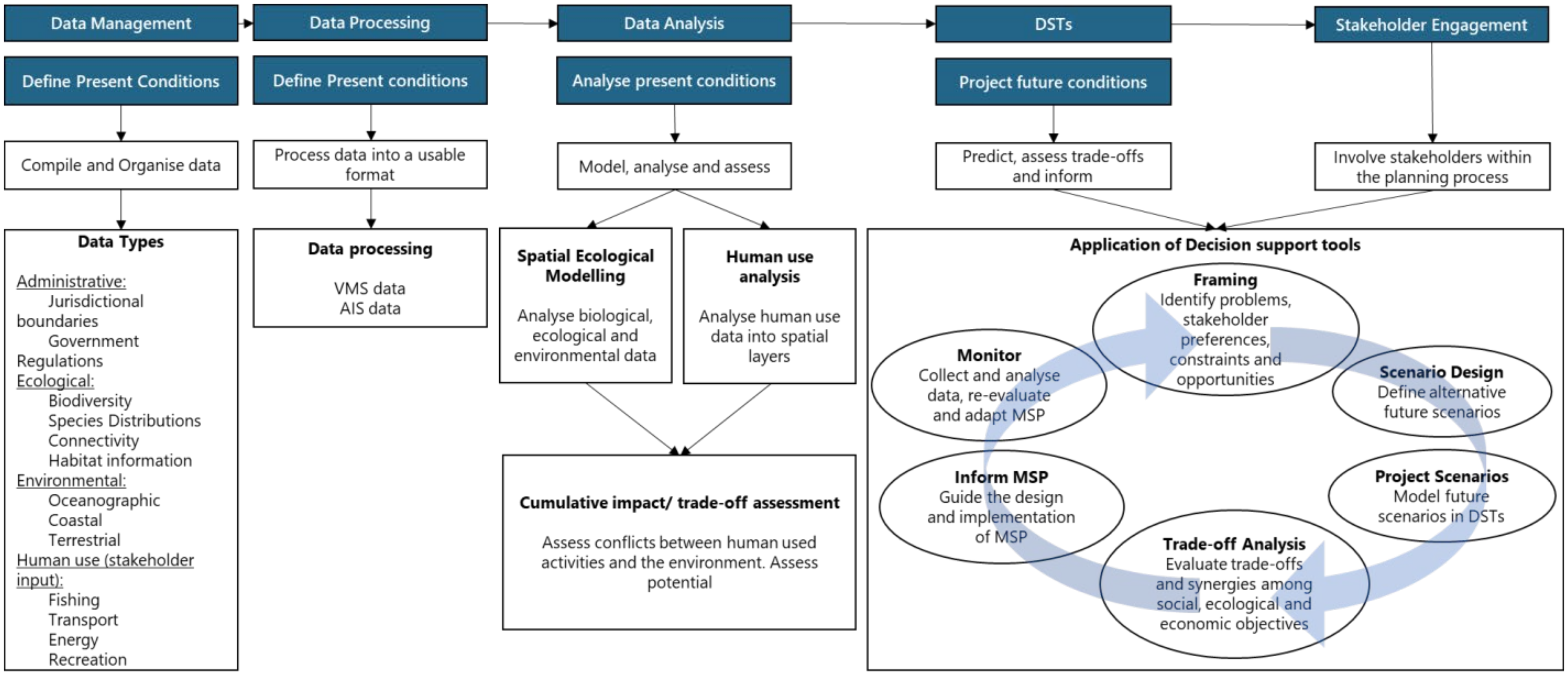


Figure G1. Key steps and associated supports tools used within the spatial planning process

G.1 Data management

Data management is a very important process within spatial planning. Information and data collected within the planning process may be underutilised without careful management. Management of data can be a time-consuming process, but data management tools can assist practitioners, allowing the organisation and management of spatially explicit databases. Data management tools can improve efficiency of data gathering and management and help to 'Gather Data and Define Current Conditions'. Within this category, tools can include collaborative data platforms, geospatial storage technologies and data assessment techniques. A geodatabase or spatial database is designed to store, query, and manipulate geographic information and spatial data. This is generally the preferred method for managing MSP data specific to an area or project. Regional initiatives may sometimes utilise Spatial Data Infrastructure to facilitate exchange of spatial data (Stamoulis and Delevaux, 2015).

G.2 Data processing

Marine planning is inherently spatial and therefore requires high quality spatial data, ideally with consistent coverage across marine plan areas. A range of data processing tools have been developed and applied to different types of data to create spatial data products indicating the spatial distribution and intensity or abundance of particular features or activities. A number of specific tools have been developed to manipulate large digital data sets that are automatically collected for commercial fishing activity and commercial shipping movements with resulting data products being used widely within marine planning processes. Such tools include AIS data tools (MMO, 2014), VMS data tools (Russo *et al.*, 2014), and assessing recreational activity (LUC, 2016). Other important tools include those developed to support habitat mapping and mobile species distributions such as seabirds (JNCC, 2012b, Mohn *et al.,* 2012, EMODnet, 2018). Such tools have been widely used to create spatial data products for a range of different purposes, but these products are particularly useful for marine planning.

G.3 Data analysis/ assessment

Data analysis or assessment tools are used to assess the potential environmental, economic or social impact of human activity. Data are used analytically in the marine planning process to provide information about trade-offs and priorities. Any decision-making process in environmental management requires both the assessment of probabilities of certain outcomes (risk analysis) and the consideration of risk management in order to assess whether a management decision will lead to the desired outcome.

Analytical methods such as spatial ecological modelling and cumulative impact assessment allows for summarisation and integration of a wide range of datasets for major planning components, enabling more efficient comparisons between data, and providing a holistic view of the current environmental state.

Analysis tools can be developed for a number of specific categories that practitioners might find useful, including tools that: assign value to the amount and type of ecosystem services delivered under different management scenarios (ecosystem service valuation; Kannen *et al.*, 2016); assess trade-offs across multiple sectors and management objectives (trade-off assessment; Alexander *et al.*, 2012); assess impacts of individual and multiple activities to ecosystems (impact assessment; Marine Scotland, 2013); provide visual context for different planning options to help stakeholders understand the array of possible planning scenarios (scenario analysis; Maes *et al.,* 2005); allow users to calculate the best returns for defined planning objectives (optimization); provide reports, maps, or other forms of information that show users whether a proposal meets one or more plan objectives (planning objective assessment); model future scenarios, for example, based on implementation of specific management measures or due to climate change predictions (forecasting); and assess the sensitivity of models, including to the amount and scale of data (sensitivity assessment; Tillin *et al*., 2010).

G.4 Decision support

Decision Support Tools (DSTs) are specifically designed to support decision making, including identification and evaluation of alternative management measures (Ehler and Douvere, 2009). Such tools may incorporate elements of data processing and impact assessment but are designed to produce outputs that will guide decision making. These can include optimisation tools e.g. Marxan or INVEST, cost benefit analysis tools or multi-criteria tools.

The use of DSTs can help solve problems that are too complex and multi-faceted to solve using human intuition or conventional approaches alone. In marine planning, the need for DSTs tend to increase with the number of planning objectives and trade-offs. In turn, the amount of data, technical challenges, and cost of tool implementation also increase (Beck *et al*., 2009).

A range of DSTs are already in use in spatial planning these include, for example; Marxan, Atlantic, MarineMap, InVEST, MIMES and ARIES. The features of these and other DSTs are provided in G.8 while a summary review of support tools is given below (Table G1).

Table G1. Overview of decision support tool applications within Marine Spatial Planning adapted from Centre for Ocean Solutions (2011)

Model	Spatial	Temporal	Ecological, Social, Economic Trade offs	Transferable and Flexible	Data Intensive	Computation Intensiv	Simple outputs	Manual Available	Ease of Use
Marxan	✓	×	✓	✓	-	×	✓	✓	✓
Ecopath	✓	✓	×	✓	✓	✓	✓	✓	×
InVEST	✓	×	✓	✓	×	×	✓	✓	✓
Atlantis	✓	✓	×	✓	✓	✓	✓	-	×
Coastal Resilience	✓	×	×	×	-	×	✓	-	✓
ARIES	✓	✓	✓	✓	×		✓	✓	✓
MIMES	✓	✓	✓	✓	×	✓	×	-	×
MarineMap	✓	×	×	✓	×	×	✓	✓	✓
MaRS	✓	✓	✓	✓	×	×	✓	-	✓
BalticNEST	✓	✓	×	×	✓	✓	✓	-	✓

The key benefits of good DSTs are their abilities to centralise and handle spatial data, the processing speed and their ease of use. It is extremely beneficial and sometimes critical, to have the DST available online to reach relevant stakeholders and increase transparency. However, one of the major limitations of DST use within MSP is their oversimplification of results. The tools require many assumptions which are embedded within the software, while these assumptions and constraints are not always transparent. This lack of transparency can cause a barrier for stakeholder engagement within the MSP process.

G.5 Stakeholder engagement

Stakeholder engagement, or public participation in relation to policy-making and implementation is required as part of the marine planning process. Article 9 of the MSP Directive states: "*Member States shall establish means of public participation by informing all interested parties and by consulting the relevant stakeholders and authorities, and the public concerned, at an early stage in the development of maritime spatial plans, in accordance with relevant provisions established in Union legislation*". As such, tool functions that support stakeholder participation and collaboration, and community outreach and engagement are important throughout all steps of the marine spatial planning process. Tools can be used to support stakeholder engagement in the spatial planning process by allowing users to:

- Discover information through data queries and map layers;
- Interact with the tool on their own (web-based) or during meetings (desk-based);
- Incorporate local and traditional knowledge about the location of uses or resources;
- Help shape the format and type of outputs based on iterative feedback to the tool developers (iterative);
- Share proposals with other stakeholders (user collaboration); and
- Write and share comments about specific aspects of plans or planning information.

Stakeholder engagement tools can include web-based GIS e.g. Marine Planning Portal, communication platforms, or marine planning challenges. They can help improve dialogue between stakeholder groups by presenting a variety of management options. Outputs from such tools are also generally designed to communicate data, increasing the transparency of the MSP process helping to avoid scepticism and concern during the decision-making process (Nelsen, 2015).

In the context of this report, the Welsh Marine Planning Portal (WMPP) provides a readily accessible tool to developers and stakeholders alike. A review of the WMPP has been carried out as part of WP1 (ABPmer, 2018b). This portal is continually being updated to capture ongoing studies and data as they become available. It is recommended that the portal is interrogated as an initial step by developers of the focus activities, or wider initiatives, to understand, for example, the potential overlap with features that may result in high consenting risk.

G.6 Tidal stream and wave energy

In addition to the tools discussed above and in G.8 and G.9 below there are several assessment tools specific to the tidal stream and wave energy industry that are now available online. The ORJIP[7] website provides a link to EIA tools that have been designed to assist with the consenting process. Wave Energy Scotland[8] manages a 'Knowledge Library' to assist with commercial development of wave energy technology, with access to key information and documents.

Two key tools, IMPACT and the Management measures tool are summarised below; however, there are a number of receptor specific tools which are applicable to marine renewable assessments such as:

- Seal collision risk model: useful for assessment of potential collision risk of seals with tidal turbines[9];
- Diving bird collision risk assessment framework for tidal turbines: provides a methodology for deriving collision rates for diving birds interacting with tidal turbines[10];

7 http://www.orjip.org.uk/eia-tools
8 https://library.waveenergyscotland.co.uk/
9 https://www2.gov.scot/Resource/0050/00509810.pdf
10 https://tethys.pnnl.gov/sites/default/files/publications/SNH-2014.pdf

- Assessing collision risk between underwater turbines and marine wildlife: provides a process for determining requirements for modelling and data collection to support assessment of collision risk[11]; and
- Bird displacement models: there are various models, these provide models and processes for assessing the potential displacement[12], and the subsequent fate of displaced birds[13].

G.6.1 IMPACT

IMPACT[14] is an online tool that has been produced by Aquatera on behalf of the Scottish Government. IMPACT provides a searchable database of the potential impacts of wave and tidal energy developments, depending on various parameters such as the technology type and environmental variables. This allows users to identify the potential key environmental impacts associated with wave and tidal energy developments and to access guidelines and recommendations for how best to assess, monitor and manage these impacts. This tool is relevant to tidal and wave energy developments in Welsh waters and provides a useful starting point for developers and regulators alike.

Limitations to the tool include: no consideration of impacts from associated activities to wave/tidal developments i.e. support vessel activity, subsea cables and other infrastructure; only assesses potential impacts on marine ecological features.

The assessment component of this study was carried out in 2011 and some information may require updating. The Scottish Government will soon undertake the first review process following which, the assessment results, recommendations and website will be updated.

G.6.2 Management measures tool

In consultation with the research and regulatory communities, it was determined that having a set of robust management measures might act as safeguards for marine animals and habitats until such time as definitive monitoring data become available to determine the level of risk from tidal and wave energy devices. At which point, mitigation measures could be reduced or removed, if applicable.

With the input of the researchers, regulators, and developers at a workshop held in May 2017 in Glasgow, the following criteria were used to develop the management measures tool[15]:

- Ensure common understanding of all parameters that describe management measures proposed for collision risk, EMF, noise, and benthic disturbance;
- Evaluate each measure for effectiveness in addressing the risk for which it is intended;
- Determine the feasibility and practicality of each measure;
- Facilitate the development of a toolbox of management measures that can be made broadly available, as they are needed; and
- Consider the use of the tool to guide initial discussions between project proponents and regulators.

11 https://www.nature.scot/sites/default/files/2017-09/Guidance%20Note%20-%20Assessing%20collision%20risk%20between%20underwater%20turbines%20and%20marine%20wildlife.pdf

12 https://www.nature.scot/sites/default/files/2017-06/Publication%202017%20-%20SNH%20Commissioned%20Report%20947%20-%20Analysis%20of%20the%20possible%20displacement%20of%20bird%20and%20marine%20mammal%20species%20related%20to%20the%20installation%20and%20operation%20of%20marine%20energy%20conversion%20systems.pdf

13 https://data.marine.gov.scot/sites/default/files//SMFS%200908%20%282%29.pdf

14 http://www.marine-impact.co.uk/index.asp

15 https://tethys.pnnl.gov/management-measures

G.7 Aquaculture

G.7.1 DEPOMOD

AUTODEPOMOD is a model used in Scotland by developers and SEPA to guide determination of licensed discharge quantities of anti-parasitic chemicals and organic waste arising from marine fish-farm operations. The recently upgraded model, NewDEPOMOD[16] predicts the impact of marine cage fish farming on the seabed, looking at the benthic impacts based on farm data (configuration, feeding rate) and environmental data (bathymetry, water currents). NewDEPOMOD was launched in June 2017 and has already been used to assess commercial fishfarm developments, such as Marine Harvest's marine salmon farm on the Isle of Muck.

G.7.2 SMILE

The Sustainable Mariculture in northern Irish sea Lough Ecosystems (SMILE) project was undertaken to develop carrying capacity models for five sea lough systems in Northern Ireland. These models use input data to simulate shellfish harvest and density dependent impacts, in addition to developing the ecological carrying capacity component to address environmental conservation.

The model is location specific, and therefore would need calibration, through a programme of data collation and collection, to be applied in Welsh locations. However, in principle, the SMILE model has the potential to provide a method for assessing impacts of aquaculture development on key environmental variables and processes.

G.7.3 Tools for Appropriate Assessment of Fishing and Aquaculture Activities

A series of tools were developed by ABPmer for the Irish Marine Institute (MI)[17] to support the assessment of fishing and aquaculture activities on Annex I habitats and Annex II species present in Natura 2000 sites. The tool develops an activity x pressure matrix to identify the pathways through which an activity affects the environment, and subsequently develops a sensitivity assessment for the key habitats that consider the type and intensity of aquaculture activities, site specific environmental conditions, habitat types and the location and overlap of these.

The tools have been developed principally for sensitive habitats within Irish waters using literature through to the publication date (2013) and as such may require update for applicability to Welsh waters and to incorporate the most up to date literature available.

16 https://www.sams.ac.uk/science/projects/depomod/

17 https://oar.marine.ie/bitstream/handle/10793/902/Report%20I%20Muds.pdf?sequence=1&isAllowed=y (and others available through the https://oar.marine.ie website)

G.8 Tool Feature Matrix

The Tool Feature Matrix highlights the general and specific features of eight of the key DSTs.

Feature Category	Feature	ARIES	Atlantis	Coastal Resilience	Cumulative Impacts	InVEST	Marine Map	MarZone	MIMES
Priority tool objective	Conservation	✓	✓	✓	✓	✓	✓	✓	✓
	Emerging uses	✓	✓	✓	✓	✓	✓	✓	✓
	Managing trade-offs	✓	✓		✓	✓	✓	✓	✓
	Education & awareness	✓	✓	✓	✓	✓	✓	✓	✓
	Scenario analysis	✓	✓	✓	✓	✓	✓	✓	✓
	Socio-economic	✓	✓		✓	✓	✓	✓	✓
Data demands and needs	Specific data types needed to use DST	✓	✓	✓	✓	✓		✓	✓
	Incorporates multiple types of data	✓	✓	✓	✓	✓	✓	✓	✓
	Resolution of required data is flexible	✓	✓	✓	✓	✓	✓	✓	✓
	Minimum amount of data required	✓	✓			✓		✓	✓
Output type	Maps	✓	✓	✓	✓	✓	✓	✓	
	Models	✓	✓	✓	✓	✓			✓
	Valuation	✓	✓			✓			✓
	Reports	✓		✓	✓	✓	✓	✓	✓
	Movies		✓	✓					✓
Validation/ peer-review	Data	✓		✓	✓	✓		✓	✓
	Code/model	✓			✓	✓			✓
	Application		✓	✓	✓	✓	✓	✓	✓
Transferability	Transferable	✓	✓			✓	✓	✓	✓
	Customized	✓	✓	✓	✓	✓	✓	✓	
Transparency	Working assumptions are stated clearly upfront	✓		✓	✓	✓	✓		✓
	Working assumptions are expressed in modelling equations or software code	✓	✓	✓					✓
	Working assumptions are understandable by all users						✓		✓
	Assumptions can be supplied by users	✓				✓			✓

Feature Category	Feature	ARIES	Atlantis	Coastal Resilience	Cumulative Impacts	InVEST	Marine Map	MarZone	MIMES
Intended audience	Public stakeholders	✓		✓	✓	✓	✓	✓	✓
	Policy makers	✓		✓	✓	✓	✓	✓	✓
	Public agency resource managers	✓		✓	✓	✓	✓	✓	✓
	Scientists	✓	✓	✓	✓	✓	✓	✓	✓
	Communities	✓		✓	✓	✓	✓	✓	✓
	Education/schools	✓		✓	✓	✓	✓	✓	✓
	Businesses	✓		✓	✓	✓	✓	✓	✓
	Project applicants	✓			✓	✓	✓	✓	
	Technical staff	✓	✓	✓	✓		✓	✓	
Support for users	Yes		✓	✓	✓	✓	✓	✓	✓
	No	✓							
Objectives	Single	✓	✓	✓	✓	✓	✓	✓	✓
	Dual	✓	✓	✓	✓	✓	✓	✓	✓
	Multiple	✓	✓		✓	✓	✓	✓	✓
Run-time/ performance	Real-time	✓			✓	✓	✓		✓
	Delay		✓	✓				✓	
Delivery mechanism for tool/model outputs	Web-based	✓		✓	✓		✓		
	Desktop	✓	✓			✓		✓	✓
	Gaming								
	Summary	✓		✓	✓	✓	✓	✓	
	Workshops	✓		✓	✓	✓	✓	✓	✓
	Mobile application								
User access	Free access	✓	✓	✓	✓	✓	✓		✓
	Fee to access							✓	
	Controlled access	✓	✓		✓		✓		✓
	No access for non-expert users								
Software	Proprietary		✓	✓				✓	✓
	Open-source	✓	✓	✓	✓	✓	✓		
User collaboration	Existing	✓	✓	✓		✓	✓		✓
	Future potential	✓			✓		✓		✓
Synergies w/ other tools	Current				✓		✓		
	Future	✓	✓	✓		✓		✓	✓
Model type	Probabilistic	✓		✓		✓			
	Deterministic	✓				✓			✓
	Dynamic	✓	✓			✓			✓
	Empirically based	✓		✓	✓	✓			

Source: Centre for Ocean Solutions, 2011

G.9 Tool Function Matrix

MSP Processing Step	Gather Data and Define Current Conditions			Identify Issues, Constraints, and Future Conditions			Develop Alternative Management Measures				Evaluate Alternative Scenarios					Monitor and Evaluate Management Measures			Refine Goals and Objectives		
Tool Function	Data Management	Mapping & Visualization	Stakeholder Participation	Mapping & Visualization	Alternative Scenarios	Stakeholder Participation	Mapping & Visualization	Alternative Scenarios	Management Measures	Stakeholder Participation	Mapping & Visualization	Alternative Scenarios	Management Measures	Stakeholder Participation	Adaptive Management	Mapping & Visualization	Stakeholder Participation	Adaptive Management	Mapping & Visualization	Stakeholder Participation	Adaptive Management
ARIES	×	×	×	×	✓	×	×	✓	✓	×	×	✓	✓	×	✓	×	×	✓	×	×	✓
Atlantis		O		O	✓		O	✓			O	✓			×	O		×	O		×
Coastal Resilience	×	×	✓	×	✓	✓	×	✓		✓	×	✓		✓		×	✓		×	✓	
Cumulative Impacts	✓	×	✓	×	O	✓	×	O	×	✓	×	O	×	✓	O	×	✓	O	×	✓	O
InVEST	O	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
MarineMap		×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	✓	×	×	✓
Marxan with Zones		O	×	O	✓	×	O	✓	✓	×	O	✓	✓	×	O	O	×	O	O	×	O
MIMES	×	×	✓	×	×	✓	×	×	×	✓	×	×	×	✓	✓	×	✓	✓	×	✓	✓

× Performs >75% of tool functions
✓ Performs 50-75% of tool functions
O Performs <50% of tool functions

H Existing Guidance

In early 2018, ABPmer reviewed existing guidance to inform NRWs future work programme and support implementation of the WNMP (Appendix I.3). It is recognised that the outputs of this previous review are of direct relevance to undertaking the three focus activities in Welsh waters and as such it is replicated (with recent updates where appropriate) within this report.

All relevant guidance documents found were recorded in the accompanying Guidance Inventory spreadsheet (see Appendix I.3) with the following document details referenced:

- Guidance number (for internal use);
- Document title;
- Author(s);
- Date of publication; and
- Hyperlink (if available, either direct to the relevant document or supporting website).

The following section provides an overview of the guidance associated with the different focus activities.

H.1 Tidal stream and wave energy

There are more than 60 relevant guidance documents available for each of the renewable technologies, with about half of these being produced in the last five years (see Guidance Inventory). These include several guidance documents specific to Welsh waters (e.g. Sparling *et al.*, 2015) and guidance in relation to seabird surveys, collision risk and acoustic monitoring (e.g. Jackson and Whitfield, 2011; EMEC, 2014; SNH, 2014 and ORJIP, 2016) as well as cumulative assessment (e.g. Celtic Seas Partnership, 2016).

Marine Energy Wales has produced consenting guidance notes to assist with the development of marine energy in Welsh Territorial Waters[18] with links to wider UK guidance where relevant. The guidance notes have been designed to be displayed in an interactive flow chart which can be found below. The web-based chart has links to previous marine energy submissions in Wales and has advice from Natural Resources Wales – Advisory and Marine Licensing.

The ORJIP website[19] provides useful links to consenting documents (ES and supporting documents) to UK wave and tidal projects. This allows developers to understand the typical consenting requirements for a given project through review of historic work carried out in this sector across the UK.

Within the IMPACT tool (see Appendix G.6.1) specific guidance on the assessment and potential monitoring requirements in relation to pressures and features from tidal stream/wave energy developments is provided. It is recommended that this tool is used to understand likely assessment and monitoring requirements.

[18] http://www.marineenergywales.co.uk/developers/consenting-guidance/
[19] http://www.orjip.org.uk/projects

H.2 Aquaculture

By comparison with renewables, the guidance on aquaculture in Wales is more limited (see Appendix I.3), particularly on consenting. However, an aquaculture toolbox has now been developed by CEFAS for Wales[20], which provides guidance to potential developers regarding the consents required, and the consultation organisations that should be contacted.

In relation to assessment there is generic guidance available on aquaculture activities and pressures (JNCC website[21]) and marine fish farming (SARF, 2007 (EIA templates); aquaculture and Natura 2000 (EC, 2016); and several on biosecurity (e.g. Welsh Government guidance on invasive aquatic species: priority marine species[22]; NRW guidance on marine biosecurity planning[23]).

Additionally, there is a wealth of guidance which has been developed for Scotland, as summarised by the Scottish Government[24]. This guidance, although developed for Scotland, can in many areas can be applied directly to the development of assessments and applications for aquaculture sites in Wales.

20 https://businesswales.gov.wales/marineandfisheries/sites/marineandfisheries/files/documents/Marine%20-%20Multi-Trophic%20Aquaculture%20%28IMTA%29%20Wales.pdf
21 http://jncc.defra.gov.uk/page-7136
22 https://beta.gov.wales/sites/default/files/publications/2018-02/invasive-aquatic-species-priority-marine-species.pdf
23 www.nonnativespecies.org/downloadDocument.cfm?id=1401
24 https://www2.gov.scot/Topics/marine/Fish-Shellfish/18716/guide

I Additional WP1 Deliverables’

I.1 Evidence Database

Evidence database delivered separately as an excel spreadsheet:

- SMMNR_WP1_Evidence Database.xlsx

I.2 Geodatabase

The geodatabase is delivered separately as an ArcGIS package and is structured as follows:

Zip folder:

- SMMNR_WP1_Geodatabases.zip

Geodatabase in the route containing all clipped data layers:

- All_Data_Clipped.gdb

There is then a folder called ‘Key Layers’ containing 5 additional geodatabases called –

- Administrative_Physical_Boundaries.gdb
- Biological_Environment.gdb
- Chemical_Environment.gdb
- Human_Environment.gdb
- Physical_Environment.gdb

I.3 Guidance Inventory

Guidance inventory delivered separately as an excel spreadsheet:

- SMMNR_WP1_Guidance Inventory.xlsx

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