



ORJIP Ocean Energy

ORJIP Ocean Energy

The Forward Look; an Ocean Energy Environmental Research Strategy for the UK

Report to: The Crown Estate, Marine Scotland and Welsh Government

Issued by Aquatera Ltd and MarineSpace Ltd

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1 INTRODUCTION

1.1 BACKGROUND

During 2013, there was an increasing recognition amongst many in the industry (developers, regulators, their advisors and the research community) that a coordinated, strategic approach would help de-risk and accelerate the consenting of wave and tidal projects in the UK. This is particularly the case for array projects yet to be consented, and those recently consented projects with consent conditions requiring technically challenging, costly and pioneering environmental monitoring programmes.

Given this recognition, throughout 2013 and early 2014, The Crown Estate and the Natural Environment Research Council (NERC) organised a series of discussions with the UK's devolved administrations, key decision makers and regulators, advisors, demonstration/commercial array-scale developers and others. There was consensus that a coordinated research programme would be a welcome development and was something worthy of continued consideration.

To kick-start development of a potential coordinated programme for the wave and tidal sectors, The Crown Estate commissioned Aquatera Ltd to undertake a desk-based study. The study sought to consolidate the key EIA/HRA issues facing the sectors and identify the current knowledge gaps and priority research areas. In addition to Aquatera involving a large number of organisations in the project's Call for Evidence, the draft report was discussed by some 50 stakeholders at a workshop organised by NERC (Edinburgh, Nov 2013).

The workshop discussions confirmed the work was comprehensive and assisted Aquatera with finalising the report. Along with a summary of the workshop by NERC, the Aquatera report was published by The Crown Estate in January 2014. To access the final report, see <http://www.thecrownestate.co.uk/media/151984/consolidation-of-eia-hra-issues-and-research-priorities.pdf>.

Following the publication of the Aquatera report in January 2014, The Crown Estate, NERC, Marine Scotland and others have continued to progress the programme. A further meeting was held in July 2014 with the regulators, Government, devolved bodies, some first array developers and others to discuss the programme structure/management, membership and funding. There was overall support and commitment shown for the proposed structure and for the programme in general, and all wished to see it progress.

The Crown Estate, Marine Scotland and Welsh Government (the Sponsors) then funded a Secretariat function to run the programme (now known as **ORJIP Ocean Energy**) and to bring industry, funders and researchers together so that the sectors' consenting risks can be addressed in a timely manner and on a strategic basis. The Secretariat role is funded for an initial pilot phase, lasting approximately 15 months to June 2016. The Secretariat function is run by Aquatera and delivery partners MarineSpace and the European Marine Energy Centre (EMEC).

The purpose of the pilot phase is to establish ORJIP Ocean Energy, progress research and monitoring projects in order to de-risk consenting of wave, tidal current and tidal range developments, gain experience of running the programme, and then to evaluate its progress and benefits.

The first key task of the Secretariat during the pilot phase was to produce a published report outlining the strategic research priorities that will form the focus of ORJIP Ocean Energy. This first draft of this report, entitled the Forward Look, was published in July 2015. The Forward Look will be maintained by the Secretariat throughout the Pilot Phase and updated on a six monthly basis. The second version is presented in the following document.

1.2 ORJIP OCEAN ENERGY – PROGRESS TO DATE AND NEXT STEPS

The ORJIP Ocean Energy pilot phase commenced in March 2015. An overview of key milestones to date is provided below:

- March 2015 – Aquatera, MarineSpace and EMEC commissioned to provide the Secretariat function for ORJIP Ocean Energy
- April 2015 – Invitations and terms of reference issued to the Steering Group and Network
- April 2015 – Call for Evidence issued to the Steering Group and Network to inform the Forward Look
- May 2015 – Draft Forward Look issued to the Steering Group
- June 2015 – Steering Group convened in Edinburgh to review the Forward Look
- July 2015 – Forward Look issued to the Steering Group and Network
- September 2015 – Mailing List established and website live
- December 2015 – Second Call for Evidence issued to Steering Group and Network to update the Forward Look
- December 2015 – Invitations issued for the first ‘expert workshop’ in partnership with OES Annex IV, ORE Catapult and EIMR (workshop to be held in February 2016)
- January 2016 – Draft second Forward Look issued to the Steering Group
- January 2016 – Second Steering Group meeting held in London
- February 2016 – Second Forward Look issued to the Steering Group and Network

During the pilot phase to date, ORJIP Ocean Energy has been promoted at a number of key events around the world including: All Energy in Glasgow, Ocean Energy Europe in Dublin, National Climate Change Conference in Manila, International Marine Renewable Energy Conference in Washington D.C., Marine Renewables Canada in Montreal, Scottish Renewables in Inverness, and various industry forums including EC Ocean Energy Forum, Bristol Tidal Energy Summit and Marine Energy Pembrokeshire’s Working Group and Consenting sub-group.

ORJIP Ocean Energy has developed strong links with other key strategic programmes including SEACAMS, OES Annex IV and ORE Catapult and has an established Network of over 65 organisations from 14 countries (see Appendix A). The website went live in September 2015 and has had over 600 unique visitors to the site to date. The Secretariat has been actively engaged with Network participants and other organisations to promote the strategic research objectives set out in the first version of the Forward Look.

Key objectives for the next stage of the pilot phase include:

- Further promotion of ORJIP Ocean Energy and the objectives of the Forward Look and further liaison with Network participants to identify organisations interested in progressing high priority projects with a particular focus on funding organisations, industry and researchers
- To maintain and update the website and include more information regarding research projects that will help meet the objectives set out in the Forward Look, key documents and links to funding opportunities
- To use the Mailing List to disseminate information regarding relevant research projects, key publications, events and funding opportunities
- To further develop links with other strategic research programmes in the UK and around the world to ensure that a truly coordinated approach to strategic environmental research is adopted by the sectors and to align objectives with those identified in the Forward Look

- To engage with project developers, funders and researchers to help ensure that results from project monitoring/research made as widely available as possible and that these are promoted through ORJIP Ocean Energy
- To develop a funding plan for the continuation of ORJIP Ocean Energy beyond the pilot phase

1.3 WORKING WITH ORJIP OCEAN ENERGY

The ORJIP Ocean Energy Secretariat would like to actively encourage Network participants and other organisations to express their interest in any of the high priority projects identified in the Forward Look. Whilst ORJIP Ocean Energy will not directly fund the projects, the Secretariat will strive to support and facilitate interested organisations or consortia in their endeavours to help meet the objectives associated with the high priority strategic research projects outlined in this Forward Look. Typical support mechanisms include:

- Identification of potential funding opportunities for high priority projects including provision of contact details
- Identification of potential project partners in the UK and around the world
- Identification of potential opportunities for research and monitoring i.e. upcoming technology deployments
- Review and research and funding programmes/strategies
- Review and endorsement of project proposals

Similarly, should Network participants be planning to pursue any of the other research areas identified in the Forward Look i.e. those identified as 'medium' or 'low' priorities for the wave and tidal sectors, ORJIP Ocean Energy would welcome any updates and may be able to provide support to organisations/consortia in the planning of research projects and dissemination of results. The contact details for the ORJIP Ocean Energy Secretariat are provided below:

| | |
|---|--|
| Ian Hutchison Secretariat Project Manager, Aquatera ian.hutchison@aquatera.co.uk Tel - +44(0) 1856 850 088 | Joseph Kidd Secretariat, MarineSpace Joseph.kidd@marinespace.co.uk Tel - +44(0) 7788 286 156 |
|---|--|

1.4 THE FORWARD LOOK

One of the key Secretariat tasks during the initial stages of the pilot phase is to develop the Forward Look which includes a prioritised list of strategic research projects to address key EIA/HRA issues and sets out the purpose, required timing and broad scope of the research projects necessary to meet ORJIP Ocean Energy's overall aim.

The aim of ORJIP Ocean Energy is to ensure that the principal EIA and HRA consenting risks for early array deployments in the wave and tidal sectors are addressed by facilitating a strategic, coordinated and prioritised approach to monitoring and research which is endorsed by industry, regulators and Statutory Nature Conservation Bodies (SNCBs).

The objective of the Forward Look is to inform the focus of ORJIP Ocean Energy; ensuring that research is focused on priority consenting EIA/HRA issues for the wave and tidal sectors, projects are coordinated to avoid duplication of effort, and key information and data gaps are addressed. The Forward Look builds upon the work previously undertaken by Aquatera; incorporating evolving sector needs and consideration of recent completed research as well as planned and ongoing research. It should be noted that whilst the previous Aquatera report focused on the wave and tidal current sectors, the Forward Look also includes tidal range.

Note: Following consultation with the Secretariat Sponsors and the ORJIP Ocean Energy Steering Group, it was determined that additional work would be required to develop a coordinated environmental research strategy for the tidal range sector. Plans are now in place to develop a draft strategy through consultation with key stakeholders in Q1 2016, the results of which will be presented in the third version of the Forward Look in Q2 2016.

1.5 OVERVIEW OF APPROACH

Using the previous Aquatera report as a baseline, the following approach was implemented to produce the Forward Look:

Task 1 – Review and update of the key findings of the previous Aquatera report

Task 2 – Production of a list of key consenting issues and risks

Task 3 – Development of research recommendations and identification of high priority strategic research projects

Task 3 – Development of outline project plans

1.5.1 Review and update of the key findings of the previous Aquatera report¹

A number of databases produced during the previous project were reviewed and updated to inform the development of the draft Forward Look, including:

- Key consenting issues and risks (Table 2.1 in the previous report)
- Research gap analysis (Table 3.1 in the previous report)
- Recommendations to address research gaps (Table 4.1 in the previous report)

This review process was informed by a second Call for Evidence and the outputs of a workshop held in Cardiff in July 2015 (refer to Box 1). All databases will be kept 'live' and maintained by the Secretariat during the pilot phase.

¹ <http://www.thecrownestate.co.uk/media/151984/consolidation-of-eia-hra-issues-and-research-priorities.pdf>.

Box 1

Call for Evidence

A Call for Evidence was issued to key stakeholders to inform the previous Aquatera report. This proved to be an effective mechanism for ensuring that the project outputs were fully informed and that the best and most up to date information was available to the team. In order to ensure that the information contained in the Forward Look was current, further Calls for Evidence were issued to the ORJIP Steering Group and Network in April 2015 December 2015. An updated list of Steering Group and Network participants is presented in Appendix A of this report. 23 responses to the Call for Evidence were received in April 2015 and 11 responses were received in December-January 2015-16.

UK Wave and Tidal Demonstration Zones workshop

A workshop was hosted by The Crown Estate, Welsh Government, Natural Resources Wales, Natural England and Scottish Natural Heritage in Cardiff in July 2015. Participants included representatives from a range of government organisations, statutory nature conservation organisations, demonstration zone and test site managers, developers and consultancies. Three key themes were discussed at the workshop including; definition of design envelopes for demonstration zones and test sites, evidence requirements for demonstration zone and test site consents and the role of demonstration zones and test sites in improving the environmental evidence base to de-risk consenting. A number of recommendations that arose from the workshop including additional strategic research projects and specific actions required to help reduce consenting risks are included in this version of the Forward Look. The full workshop report is available online².

1.5.2 Production of list of key consenting issues and risks

The long list of consenting issues and risks presented in the previous Aquatera report was reviewed and updated following analysis of the responses to the Call for Evidence. The list was also expanded to include those relevant to tidal range developments. A screening process was then undertaken to identify 'key' consenting issues and risks (refer to Chapter 2). Any changes to the list of key consenting issues and risks identified in the previous Aquatera report were noted.

1.5.3 Development of research recommendations and identification of high priority projects

The research gap analysis undertaken during the previous Aquatera project was reviewed and updated. Research projects with the potential to address each gap identified were defined and from this 'long list', high priority strategic research projects that have the potential to help address key consenting issues and risks were identified.

1.5.4 Development of outline project plans

Outline project plans were developed for each high priority strategic research project. Each plan includes the following:

- Clear definition of the required outputs from the Research Project(s)
- Timescales needed for delivery of outputs in order for them to be useful
- Activities and information required, type of organisations needed
- Key questions that the project(s) will attempt to answer (link to list of key issues)
- Status of any projects currently planned to be undertaken, details of whether funding has been secured, overview of the project team, timescales etc. (link to the research gap analysis database)
- Locations/sites or at least characteristics of sites likely to be required

² Available at: <http://www.thecrownestate.co.uk/media/501992/ei-uk-wave-and-tidal-demonstration-zones-workshop.pdf>

- Indicative scale of cost for delivering the required research based on consultation with Network members
- Identification of candidate project Lead and Funders, based on consultation with Network members

1.6 STRUCTURE OF THE FORWARD LOOK

The Forward Look is structured as follows:

- **Chapter 2:** List of key consenting issues and risks
- **Chapter 3:** Research recommendations and list of priority projects
- **Chapter 4:** Outline project plans
- **Chapter 5:** Conclusions and next steps
- **Appendix A:** ORJIP Ocean Energy Steering Group and Network participants
- **Appendix B:** Issues/risks no longer considered to be key strategic consenting issues
- **Appendix C:** Research gap analysis

1.7 NEXT STEPS

The development schedule for the Forward Look is outlined in the following table:

| | |
|---|----------------------------|
| First draft of the 1 st Forward Look issued to the Steering Group | Early June 2015 |
| First draft of the Forward Look discussed and agreed at the 1 st Steering Group meeting | 16 th June 2015 |
| 1 st Forward Look issued to the Network | July 2015 |
| Draft 2 nd Forward Look issued to the Steering Group and discussed at the 2 nd Steering Group meeting | January 2016 |
| 2 nd Forward Look issued to the Network | February 2016 |

2 LIST OF KEY CONSENTING ISSUES AND RISKS

The 'long list' of key EIA/HRA issues presented in the previous Aquatera report³ for TCE and NERC was used as the basis for this task. This was updated based upon the responses to the Calls for Evidence (refer to section 1.5.1). A screening process was then undertaken to identify 'key issues'. Within the context of this project and the study objectives, the following criteria were used to identify the key EIA/HRA issues:

- **Project type – is the issue relevant to wave projects, tidal stream projects, tidal range or all three?** Issues relevant to all/a number of wave/tidal technology or project types were identified as key issues.
- **Strategic relevance – can and should the issue be addressed at a strategic level?** Issues that should be addressed at a project/site specific level were **not** considered as key issues.
- **Project scale – is the issue relevant to demonstration scale or commercial scale projects?** At this stage, issues relevant to demonstration scale arrays were identified as key issues. It was considered that issues likely to be relevant at commercial scale only can be tackled in the longer term and are therefore not priorities in the immediate/near-term. However, issues considered to be only relevant at commercial scale that were identified as high priorities by the wave and tidal energy sectors⁴ and for which strategic research at demonstration scale would inform commercial scale EIA/HRA, were also identified as key issues during this process.
- **Regulatory issues – is the issue a current concern for regulators and advisors that developers are required to address within project EIA/HRA?** Issues facing developers due to current regulatory concerns (including identified and perceived risks) that can be addressed through coordinated strategic research were identified as key issues.

From the longlist of key EIA/HRA issues, a total of 27 issues were identified as 'key strategic consenting issues' currently facing the wave and tidal industries. A summary of each of these issues including which industry they are relevant to is presented in Table 2.1. A summary of those issues no longer considered to be 'key strategic consenting issues' are presented in Appendix table B.1.

Please note that consenting issues and risks are not presented in any particular order.

Please note that key consenting issues and risks specific to tidal range developments are not included in the following table. Following consultation with the ORJIP Ocean Energy Steering Group and Network, it was determined that a similar process to that undertaken for The Crown Estate and NERC in 2013 to identify and consolidate consenting issues and research priorities for the wave and tidal current sectors would benefit the tidal range sector. Further information regarding this process will be communicated to the ORJIP Ocean Energy Network through the Mailing List and an updated list of consenting issues and risks for tidal range will be provided in the third Forward Look.

³ <http://www.thecrownestate.co.uk/media/151984/consolidation-of-eia-hra-issues-and-research-priorities.pdf>.

⁴ These issues were identified as high priorities during the consultation process for the previous Aquatera report.

Table 2.1 List of key strategic consenting issues and risks – wave and tidal energy

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|---------------------------------|--|------------------------------------|-------------------------------------|---|-------------------------------|--|
| Ecological environment | | | | | | |
| 1. Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Tidal current | Yes, relevant to all tidal projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 1. Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Tidal current | Yes, relevant to all tidal projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 1. Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Tidal current | Yes, relevant to all tidal projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 1. Collision risk | 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines | Tidal current | Yes, relevant to all tidal projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 1. Collision risk | 1.5 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 | Tidal current | Yes, relevant to all tidal projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 2. Underwater noise | 2.1 Lack of available acoustic data from operational devices and arrays | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 2. Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 3. Electromagnetic fields (EMF) | 3.1 Further data and information regarding the possible effects of EMF from transmission cables on fish would improve confidence in EIA and HRA | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 4. Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | Both | Yes, relevant to all projects | Commercial - this issue was identified as a high priority during the Draft Report consultation process. | Yes | This remains a key strategic consenting issue. |

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|---------------------------------------|--|------------------------------------|-------------------------------|------------------------------------|-------------------------------|--|
| 5. General | 5.1 Further strategic baseline data (distribution, abundance, seasonality, etc.) for marine mammals and basking sharks is required to better understand use of potential development areas | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue |
| 5. General | 5.2 Further strategic baseline data (distribution, abundance, seasonality, etc.) for birds is required to better understand use of potential development areas | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue |
| 5. General | 5.3 Further strategic baseline data (distribution, abundance, seasonality, etc.) for migratory fish is required to better understand use of potential development areas | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue |
| 5. General | 5.4 An agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA is required | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 5. General | 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA/HRA | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 5. General | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| Human environment | | | | | | |
| 6. Impacts on commercial fisheries | 6.1 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 | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 7. Impacts on shipping and navigation | 7.1 Difficulties with assessing and mitigating the potential cumulative impacts on shipping and navigation due to uncertainty around risks that may arise from a number of projects | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|---|---|------------------------------------|-------------------------------|--|-------------------------------|--|
| 8. Impacts on seascape | 8.1 Lack of regional and local coastal landscape character assessments and objective assessment criteria to inform Seascape, Landscape and Visual Impact Assessment | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 8. Impacts on seascape | 8.2 Lack of understanding regarding the economic value of seascape and any change in this as a result of renewable activities | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This remains a key strategic consenting issue. |
| 9. Social and economic impacts on local communities | 9.1 Difficulty with identifying, assessing, mitigating and managing potential cumulative social and economic impacts from marine energy developments and changes to existing maritime activity | Both | Yes, relevant to all projects | Commercial scale and 'clusters' of demonstration scale projects | Yes | This remains a key strategic consenting issue. |
| Physical environment | | | | | | |
| 10. Impacts on physical processes | 10.1 Development of hydrographic models to predict the effects of changes in water flow and energy removal caused by (a) the physical presence of the device in the water (b) the removal of energy and secondary effects of changes in water flow and energy removal | Both | Yes, relevant to all projects | Commercial but valuable research could be undertaken around demonstration array projects | Yes | This remains a key strategic consenting issue. |
| 10. Impacts on physical processes | 10.2 Validation of hydrographic models to help predict the effects of changes in water flow and energy removal at commercial scale | Both | Yes, relevant to all projects | Commercial but valuable research could be undertaken around demonstration array projects | Yes | This remains a key strategic consenting issue. |
| Regulatory | | | | | | |
| 11. Regulatory processes | 11.1 Methods/processes are required to help manage perceived and identified environmental risks that may arise from wave and tidal developments to ensure that project level requirements are proportionate | Both | Yes, relevant to all projects | Demonstration and commercial | N/A | This remains a key strategic consenting issue. |
| 11. Regulatory processes | 11.2 Methods/processes are required to predict and measure potential cumulative impacts around clusters of lease areas | Both | Yes, relevant to all projects | Demonstration and commercial | N/A | This remains a key strategic consenting issue. |

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|--------------------------|---|------------------------------------|-------------------------------|------------------------------------|-------------------------------|--|
| 11. Regulatory processes | 11.3 Agreement is required on the approach to applying a design envelope approach to consenting wave and tidal arrays | Both | Yes, relevant to all projects | Demonstration and commercial | N/A | This remains a key strategic consenting issue. |
| 11. Regulatory processes | 11.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans, incorporating adaptive management strategies, for commercial scale wave and tidal arrays | Both | Yes, relevant to all projects | Demonstration and commercial | N/A | This remains a key strategic consenting issue. |
| 11. Regulatory processes | 11.5 There is uncertainty as to how proposed Special Areas of Conservation for harbour porpoise will be considered with regards to consented sites and future applications | Both | Yes, relevant to all projects | Demonstration and commercial | N/A | This is a key strategic consenting issue. |

3 IDENTIFICATION OF PRIORITY RESEARCH PROJECTS

Following the identification of key consenting issues and risks, the second task in producing the Forward Look was to identify where research can help reduce uncertainty around these key consent issues at a strategic level. A screening process was then applied to identify **high priority strategic research projects**. An overview of the approach implemented to identify the high priority strategic research projects that have the ability to address key consenting issues and risks that will form the initial focus of ORJIP Ocean Energy is presented in the following figure:

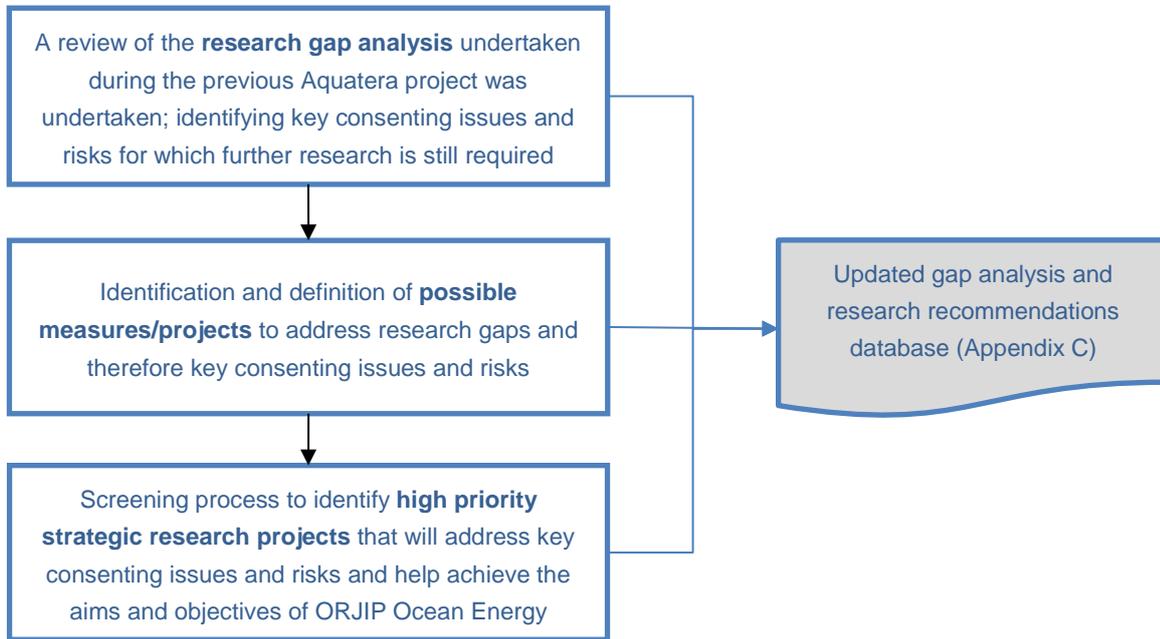


Figure 1 Identification of high priority strategic research projects

As shown above, the ‘gap analysis and research database’ produced during the previous Aquatera project was reviewed and updated during this task. The updated database is presented in Appendix C of this report. This includes the following information in relation to each key consenting issue/risk identified in Table 2.1:

- List of research gaps in relation to each key consenting issue and risk identified during the project
- List of possible research projects that could address each research gap
- Results of the screening process implemented to identify the high priority strategic research projects that will form the focus of ORJIP Ocean Energy

In line with the aim of ORJIP Ocean Energy which includes a commitment to help focus strategic research on: “....**the principal EIA and HRA consenting risks for early array deployments in the wave and tidal sectors are addressed by facilitating a strategic, coordinated and prioritised approach to monitoring and research....**”, a set of assessment criteria was applied to all possible research projects within the database to identify high priority strategic research projects that will form the focus of ORJIP Ocean Energy:

| | |
|------------------------|---|
| High priority | Projects required in the immediate near-term that would benefit from a strategic approach and have the potential to address key consenting risks relevant to early array developments in line with the overarching aim of ORJIP Ocean Energy. |
| Medium priority | Projects that would benefit from a strategic approach that have the potential to address key consenting issues but are not considered to be short-term priorities for the wave and tidal sectors. |
| Low priority | Projects that may benefit from a strategic approach and have the potential to address aspects of key consenting issues. The need for these projects will be informed by the outcomes of other higher priority research projects. |

As a result of this screening process, 22 high priority strategic research projects were identified. Each of these was considered by the team in relation to ongoing and planned research. Those for which immediate further research/action is required, are listed in Table 3.1. Those for which there is considered to be sufficient ongoing work or research planned in the near-term, are listed in Table 3.2.

Projects are listed along with the corresponding consenting issues in Table 3.1. The relevance of each project to the tidal current, wave and tidal range sectors is also outlined.

Please note that all medium and low priority projects identified during the screening process are listed in Appendix C.

Please note that although a number of the high priority projects outlined in the following table are relevant to tidal range developments, strategic projects specifically relevant to tidal range developments have not yet been identified. These will be considered following the identification of key consenting risks and issues as described in Chapter 2. More information will be communicated through the ORJIP Ocean Energy Mailing List and in the third Forward Look in Q2 2016.

Table 3.1 High priority strategic research projects identified to address key strategic consenting issues

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|-------------------|--|---------------|------|-------------|
| A. Collision risk | A.1 Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines | ✓ | X | X |
| | A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish | ✓ | X | X |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|---------------------|--|---------------|------|-------------|
| | and tidal turbines | | | |
| | A.3 Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines 1.5 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 | ✓ | X | X |
| B. Underwater noise | B.1 Establishment of an acoustic ‘evidence base’ for operational devices and arrays | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 2.1 Lack of available acoustic data from operational devices and arrays 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | ✓ | ✓ | X |
| | B.2 Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | ✓ | ✓ | ✓ |
| C. Displacement | C.1 Development of an agreed approach to assessing the potential effects and consequences of displacement from wave and tidal arrays | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | ✓ | ✓ | ✓ |
| D. Socio-economics | D.1 Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 9.1 Difficulty with identifying, assessing and managing potential cumulative social and economic impacts from marine energy developments and changes to existing maritime activity | ✓ | ✓ | ✓ |
| E. General | E.1 Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines | | | |
| | Relevant key issue(s) <ul style="list-style-type: none"> 1.1 The nature of any interactions between diving birds and tidal turbines is uncertain 1.2 The nature of any interactions between marine mammals and basking sharks and tidal turbines is uncertain | ✓ | X | X |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|----------------------|---|---------------|------|-------------|
| | <ul style="list-style-type: none"> 1.3 The nature of any interactions between migratory fish and tidal turbines is uncertain 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | | | |
| | <p>E.2 Development of mitigation measures for identified and potential impacts of wave and tidal developments</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> 1.5 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 | ✓ | ✓ | ✓ |
| | <p>E.3 Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> 1.5 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 | ✓ | X | X |
| | <p>E.4 Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal current projects</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | ✓ | ✓ | ✓ |
| | <p>E.5 Review and dissemination of findings of environmental monitoring studies</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> This is relevant to ALL key consenting issues | ✓ | ✓ | ✓ |
| F. Regulatory issues | <p>F.1 Review of PBR approach to regulation including consideration of alternatives</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | ✓ | ✓ | ✓ |
| | <p>F.2 Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process</p> <p>Relevant key issue(s)</p> <ul style="list-style-type: none"> 11.1 Methods/processes are required to help manage perceived and identified environmental risks that may arise from wave and tidal | ✓ | ✓ | ✓ |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|----------------------------|---|---------------|------|-------------|
| | developments to ensure that project level requirements are proportionate | | | |
| | F.3 Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays. Relevant key issue(s) <ul style="list-style-type: none"> 11.3 Agreement is required on the approach to applying a design envelope approach to consenting wave and tidal arrays | ✓ | ✓ | ✓ |
| | F.4 Development and agreement of methods/processes for developing Project Environmental Management Plans, incorporating mitigation measures and adaptive management strategies, for demonstration and commercial scale wave and tidal arrays. Relevant key issue(s) <ul style="list-style-type: none"> 11.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans, incorporating adaptive management strategies, for commercial scale wave and tidal arrays | ✓ | ✓ | ✓ |
| | F.5 An agreed approach to undertaking any HRA with regards to proposed SACs for harbour porpoise is required Relevant key issue(s) <ul style="list-style-type: none"> 11.5 There is uncertainty as to how proposed Special Areas of Conservation for harbour porpoise will be considered with regards to consented sites and future applications | ✓ | ✓ | X |
| G. Shipping and navigation | G.1 Development of agreed methods/processes for assessing, mitigating and managing potential impacts on shipping and navigation Relevant key issue(s) 7.1 Difficulties with assessing and mitigating the potential cumulative impacts on shipping and navigation due to uncertainty around risks that may arise from a number of projects | ✓ | ✓ | ✓ |

Outline project plans have been developed for each high priority strategic research project listed in Table 3.1. These are presented in Chapter 4.

Those for which there is considered to be sufficient ongoing work or research planned in the near-term, are listed in Table 3.2.

Table 3.2 High priority strategic research projects with sufficient research underway/planned

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|-------------------|--|---------------|------|-------------|
| A. Collision risk | A.4 Further development of collision risk models for marine mammals, fish and birds to inform EIA/HRA Relevant key issue(s): <ul style="list-style-type: none"> 1.1 The nature of any interactions between diving birds and tidal turbines is uncertain 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain 1.3 The nature of any interactions between migratory fish and tidal turbines is uncertain | ✓ | X | X |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|---------------------|---|---------------|------|-------------|
| | <ul style="list-style-type: none"> 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA <p>Current status: SNH has contracted Bill Band to develop guidance on Collision Risk Assessment of Marine Wildlife with Tidal Turbines. This project will review the three approaches most commonly used to date for underwater collision risk assessment (Band CRM, SRSL Encounter Rate Modelling (ERM) and RPS Exposure Time Modelling for Birds (ETM). This guidance has been out for consultation and is due for publication in February 2016 (Start: Dec 2014. End: Feb 2016. Contractor: Bill Band. SNH Contact: Chris Eastham (chris.eastham@snh.gov.uk)).</p> <p>This work will help identify need/scope for further research.</p> <p>Relevant projects currently planned or underway:</p> <ul style="list-style-type: none"> Marine Scotland/SNH - Update of Collision Risk Estimation for Harbour Seals and Tidal Turbines. An Individual Based Model (IBM) software system for marine mammals has been developed at Swansea University and is to be released "open source" in 2016-17. It is to be tested against historic data collected at Ramsey Sound. MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate | | | |
| B. Underwater noise | <p>B.3 Gather acoustic data around single operational machines</p> <p>Relevant key issue(s):</p> <ul style="list-style-type: none"> 2.1 Lack of available acoustic data from operational devices and arrays 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete <p>Current status: As outlined in Project B.1 (see Table 3.1), an evidence base has been developed by NERC, collating available information and data to improve knowledge of underwater noise emitted by marine renewable devices around the coast of the UK. This evidence base will inform discussions between regulators and industry regarding possible future consenting and survey requirements associated with underwater noise.</p> <p>This work will help identify need/scope for further research.</p> <p>Relevant projects currently planned or underway:</p> <ul style="list-style-type: none"> Acoustic Monitoring of Wave Energy Converters (ends September 2016) (Dr. Brian Polagye University of Washington). Ongoing acoustic monitoring and methods development for wave energy converters at the Wave Energy Test Site (Hawaii, US) in conjunction with University of Hawaii and Sea Engineering. Deployment of bottom mounted, mid-water, and drifting instrumentation packages. | ✓ | ✓ | X |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|------------|--|---------------|------|-------------|
| E. General | <p>E.6 Establish appropriate and proportionate objectives and methodologies for site characterisation surveys to inform EIA/HRA</p> <p>Relevant key issue(s):</p> <ul style="list-style-type: none"> 5.4 An agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA is required <p>Current status:</p> <p>There is a significant amount of strategic work underway in this area. Outputs of these key projects will inform the need for or scope of any further strategic research. Future work should include the development of site characterisation survey design methods for small sites as methods developed for large sites are not appropriate. This should be informed by a review of characterisation studies for consented projects to date, with a view to establishing good practice principles.</p> <p>Recently completed project(s):</p> <ul style="list-style-type: none"> NRW Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales (July 2015) (http://www.naturalresources.wales/our-evidence-and-reports/guidance-to-inform-marine-mammal-site-characterisation-requirements-at-wave-and-tidal-stream-energy-sites-in-wales/?lang=en.) NRW commissioned report carried out by SMRU Consulting. This project developed a framework for assessing risk to marine mammals from wave and tidal stream developments and provides guidance on how to tailor surveys to provide better information for impact assessments. <p>Relevant projects currently planned or underway:</p> <ul style="list-style-type: none"> RiCORE (Work package 4 – Pre-consent survey optimisation). This work package is concerned with: Identification of current requirements; identification of commonalities; survey guidance; cost reduction opportunities; and socio-economic engagement. Marine Scotland review of Survey, Deploy and Monitor strategy. TURNKEY Work Package (WP) 2 compliments the work being carried out on EQUIMAR which delivered a suite of high level protocols covering site selection, device engineering design and the MaREE programme in Scotland which established the baseline conditions of wave and tidal sites. http://www.turnkeyproject.eu/, July 2013 to September 2015. A survey and monitoring framework for marine birds at tidal lagoon energy projects in Wales. NRW commissioned report, carried out by WWT Consulting. To be completed by April 2016. Project management: NRW (Patrick Lindley, Marine Ornithologist). The aim of this project is to produce a framework to enable a consistent approach to the gathering of data to inform consenting and monitoring for tidal lagoon developments. The framework will aid development of NRW's advice on future environmental assessments for proposed tidal energy projects in Wales. Although the focus of the work is tidal range projects, some of the principles are likely to also be relevant for wave and tidal stream projects. | ✓ | ✓ | ✓ |

| Topic | Recommended research project and key consenting issue | Tidal current | Wave | Tidal range |
|----------------------|--|---------------|------|-------------|
| F. Regulatory issues | <p>F.6 Methods are required for determining connectivity of mobile qualifying species from protected sites with development areas</p> <p>Relevant key issue(s):</p> <ul style="list-style-type: none"> 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA and HRA <p>Current status:</p> <p>Work currently underway regarding connectivity of qualifying interests with SPAs by SNH will inform the need/scope for any future research in this area.</p> <p>The inter-agency marine mammal working group work on marine mammal management units and discussions about harbour porpoise SACs should help clarify role of management units and connectivity issues.</p> <p>Relevant projects currently planned or underway:</p> <ul style="list-style-type: none"> PhD (funded by NERC and NRW) investigating Protosociality in colonially breeding grey seals. Timetable: 2013-2016. Project management: Dr Patrick Pomeroy (SMRU, University of St Andrews) and Dr Tom Stringell (NRW). This project will use photo ID to explore social structures in grey seals and site fidelity/connectivity of seals in Irish Sea (including between protected and non-protected areas) using the Welsh pelage database (EIRPHOT). Field investigations of early migration behaviour of salmon smolts in Scottish nearshore waters planned for 2016. Environmental Research Institute, North Highland College UHI. Passive and Active Acoustic Monitoring of Marine Renewable Energy (until 2017). Dr. John Horne (University of Washington) and Dr. Sarah Henkel (Oregon State University). Development and testing of methods to track fish through wave energy sites. | ✓ | ✓ | ✓ |

4 OUTLINE PROJECT PLANS

4.1 PROJECT PLANS FOR ISSUES RELEVANT TO WAVE AND TIDAL CURRENT

In the following sections, the high priority strategic research projects for the wave and tidal current sectors are developed. A number of specific ‘candidate projects’ and ‘actions’ are listed for each high priority strategic research project. Please note that any additional candidate projects or actions that would help meet the objectives outlined under each high priority strategic research project would be welcomed and would be included in the third Forward Look in Q2 2016.

4.1.1 Collision risk

| Project A.1 | Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment |
|---|---|
| Aim | To monitor the behaviour of marine mammals around operational tidal turbines to build an evidence base to inform collision risk assessments for tidal projects and to help determine whether or not collision is ever likely to be an issue for marine mammals. |
| Objective | <p>There is concern that collisions between marine mammals and operational tidal turbines may occur. Monitoring studies to date have been limited and have largely focused on collision detection, providing little evidence to help reduce uncertainty.</p> <p>Strategic monitoring studies around single turbines and first arrays have the potential to provide evidence to reduce uncertainty around collision risk, evasion and avoidance behaviour. This evidence will help determine whether or not collision is every likely to be an issue for marine mammals; establishing the need for future baseline characterisation surveys and post-consent mitigation and monitoring.</p> |
| Required outputs | <ul style="list-style-type: none"> • To determine whether collisions are detectable • Records of any collisions with tidal turbines • Data to help determine the likelihood/probability of occurrence • To agree fixed definition for key behavioural responses (avoidance, evasion, etc). • Greater understanding regarding reef effects and fish aggregation behaviour and the indirect effects of increased collision risk for predators • Data to help establish avoidance and evasion rates for use in collision risk modelling • Improved understanding of evasion behaviour • Evidence base to inform future consenting processes and post-consent mitigation and monitoring requirements |
| Location | Any installed tidal turbines at test sites including EMEC, Meygen (Inner Sound), TEL (Ramsey Sound), Minesto (Strangford Lough) |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • A review of collision risk monitoring undertaken to date will be included in the OES Annex IV State of the Science Report, which will be published in Q1 2016. This will include standard definitions for key behavioural responses (avoidance, evasion, etc) • Scottish Government Demonstration Strategy • Monitoring undertaken around tidal turbines including those deployed at EMEC, ORPC (USA), OpenHydro (Canada), Verdant Power (USA) • Monitoring planned at MeyGen. MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate • Monitoring planned at Tidal Energy Ltd’s DeltaStream Demonstrator project in Ramsey Sound (use of PAM and AAS to monitor behavioural response of a marine mammals in close proximity of an operating turbine) • Advanced Telemetry and Bio-logging for Investigating Grey Seal Interactions with Marine Renewable Energy Installations, January 2016 to January 2019 (PhD – University of Swansea KESS programme/NRW). Supervised by Dr Tom Stringell (NRW) and Dr James Bull, Dr Luca Borger and Prof Rory Wilson (University of Swansea). This project will use cutting-edge telemetry and bio-logging devices to quantify and understand interactions between grey seals |

| Project A.1 | Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment |
|----------------------|--|
| | <p>and potential MRE installations. Daily diary tagging technology (Swansea Live Animals Movements (SLAM) tags – advanced accelerometers), will be used to monitor and assess in-water seal behaviour and energy expenditure. It is hoped that some of the tags will be used on animals from Ramsey Island to enable interactions around the DeltaStream device to be monitored.</p> <ul style="list-style-type: none"> • SEACAMS II (planned): Investigation of Marine mammals behaviour in close proximity of an operating turbine. • Understanding of the collision risk of marine mammals with underwater rotating equipment and the behavioural response of different animal species. Ongoing R&D project by Tidal Energy Limited at Ramsey Sound – no results available as yet but equipment procured via Carbon Trust/WG grant prior to early termination. • University of Washington’s Intelligent Adaptable Monitoring Package (iAMP), January 2015 to June 2017 (Dr. Brian Polagye). Development and field deployment of cabled and autonomous integrated monitoring packages for marine renewable energy. Deployments planned for late 2016 off the Oregon Coast (US, pre-installation wave energy monitoring) and early 2017 at the Wave Energy Test Site (US, post-installation wave energy monitoring). |
| Candidate project(s) | <ul style="list-style-type: none"> • Deployment of FLOWBEC or EMEC’s Integrated Environmental Monitoring Platform at existing sites e.g. EMEC, MeyGen (Possible funders - Scottish Enterprise/SDI/DECC SEA programme) • Extension/expansion of TEL monitoring programme in Ramsey Sound including additional data analysis, particularly sonar and PAM data • SME deployment at EMEC in 2016 • Potential for new instrumentation and/or algorithms to be implemented by third parties during the Intelligent Adaptable Monitoring Package (iAMP) deployments planned for late 2016 off the Oregon Coast (US, pre-installation wave energy monitoring) and early 2017 at the Wave Energy Test Site (US, post-installation wave energy monitoring). • Analysis of existing underwater video footage gathered around devices at EMEC |
| Recommended actions | <ul style="list-style-type: none"> • Investigate opportunities or mechanisms for collaborative data sharing or strategic monitoring across test sites, demo zones and projects (ORJIP Ocean Energy and Project Managers) |

| Project A.2 | Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals |
|--|--|
| Aim | To help establish whether key species are ever likely to be struck by operational tidal turbines |
| Objectives | <p>Due to a perceived risk that collision events with tidal turbines may occur, tidal developers are required to install highly precautionary collision risk monitoring systems to detect any potential events and to increase understanding as to the likelihood of collision events occurring. However, targeted lab-based research and modelling into the potential for collision events to occur and the possible consequences of any collision events may help to determine if collisions with tidal turbines are a real concern, or not, for key species within shorter timescales. Laboratory testing and modelling may also be a more cost effective mechanism for investigating the likelihood and consequences of collision risk with tidal turbines than monitoring at sea.</p> <p>Such studies have the potential to provide evidence that will help determine the possible likelihood and probability of any collision events occurring. This evidence will directly inform the need for future baseline characterisation surveys and post-consent mitigation and monitoring.</p> |
| Required outputs | <ul style="list-style-type: none"> • Modelling hydrodynamics (size of animal, buoyancy, swim speed, etc) to investigate if marine mammals and diving birds would actually be hit and the consequences of collision. • Better understanding of potential impact pathways for single machines and arrays; including arrays with a mixture of technologies |
| Location | N/A |
| Relevant projects currently planned or | <ul style="list-style-type: none"> • MS-Led Project with SNH Contribution: Fine Scale Seal Density Mapping. • Seal at-sea distribution, movements and behaviour, SMRU, via DECC SEA site • Marine Scotland project: Update in collision risk estimation for harbour seals and tidal turbines |

| Project A.2 | Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals |
|----------------------|--|
| underway | <ul style="list-style-type: none"> • Monitoring undertaken around tidal turbines including those deployed at EMEC, ORPC (USA), OpenHydro (Canada), Verdant Power (USA) • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate • Monitoring planned at TEL (Ramsey Sound) • PNNL harbour porpoise study re. consequence of collision with MCT • Comparison of blade strike modelling results with empirical data (Ploskey and Carlson, PNNL 2004) • Assessment of strike of adult killer whales by an OpenHydro Tidal Turbine (PNNL) • SMRU work investigating the physical consequences of potential blade strikes on marine mammals |
| Candidate project(s) | <ul style="list-style-type: none"> • CFD modelling to investigate the likelihood and consequences of collision events (Possible lead: Queens University Belfast/Edinburgh University) • Seal tagging at an existing development/test site |

| Project A.3 | Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays |
|------------------|---|
| Aim | To support the development of technologies and agreed approaches for detecting and identifying wildlife, monitoring wildlife behaviour and interactions with machines and support structures in high energy environments. |
| Objective | <p>The use of monitoring systems which have already been developed has not been exploited optimally because of lack of funding. There are also significant challenges regarding use of existing technology which currently undermine our ability to monitor at the scale of arrays, and over timescales needed to obtain useful data. Hence, powering up, marinisation and ease of deployment / recovery are all considerations which need to be urgently addressed, as is the potential to deploy monitoring technology in tandem with devices / foundations.</p> <p>It is also clear that some of the existing technologies do not collect data at appropriate spatial scales to be of use, and development of appropriate software / data transfer systems often lags behind the development of the hardware. Development of GPS tagging technology has proceeded apace and there is much to gain from use of telemetry and tagging at array deployment sites.</p> <p>Further development of suitable instrumentation and methodologies are clearly required to enable strategic monitoring studies to proceed. Strategic monitoring studies around single turbines and first arrays have the potential to provide evidence to reduce uncertainty around collision risk, evasion and avoidance behaviour. This evidence will help determine whether or not collision is every likely to be an issue for marine mammals; establishing the need for future baseline characterisation surveys and post-consent mitigation and monitoring.</p> |
| Required outputs | <ul style="list-style-type: none"> • Critique of the capabilities of existing technologies including the suitability, quality, reliability, durability, limitations, etc. for use in high energy marine environments combined with an analysis of the specific development/innovation needs to allowing detection and monitoring at the scale of arrays. • Development/trialling of suitable cost-effective instruments and methodologies for use in high energy environments to monitor wildlife behaviour and to detect and quantify incidence of any collisions during operation of single test devices and first arrays. • Development of a fully automated, cost effective collision risk detection system with integrated software package allowing first array developers to deploy and monitor. • Development of cost effective monitoring systems to gather behavioural data to inform EIA/HRA. • Advancement in battery power/redundancy, cable protection and performance • Solutions to video camera fouling issues • Solutions to data storage and management issues (data mortgages) |
| Location | Test sites and first arrays |

| Project A.3 | Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays |
|---|---|
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • ORJIP Review of Acoustic Deterrent Devices and Marine Mammal Mitigation for Offshore Wind Farms (SMRU Marine and Xodus) Phase 2 (stage 1 and stage 2): Exploring the possibility of using ADDs as a ‘replacement’ for MMO/PAM mitigation. Although the focus of the work has been on offshore wind, some of the principles might apply to ocean energy. • Scottish Government Demonstration Project at Meygen • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate • Mammal impact on tidal turbine blades. Relevant Research: ORE Catapult Tidal Blade Collision Sensor (report due Q1 2016). Censis, with project funding contributions from NERC and SNH is delivering a study investigating the feasibility of adapting and developing existing sensor technology to detect final moments before impact and blade damage assessment. Insights will be made publically available • Further use and development of the FLOWBEC platform • SMRU/NERC/MREKE funded project to develop self-contained buoy tracking system (report due soon) • Use of sonar and passive acoustics at Strangford Lough (MCT) and • Ramsey Sound (TEL) using sonar and passive acoustics and stress transducers and accelerometers to see if collisions are physically ‘detectable’ • University of Washington’s Intelligent Adaptable Monitoring Package (Iamp), January 2015 to June 2017 (Dr. Brian Polagye). Development and field deployment of cabled and autonomous integrated monitoring packages for marine renewable energy. Deployments planned for late 2016 off the Oregon Coast (US, pre-installation wave energy monitoring) and early 2017 at the Wave Energy Test Site (US, post-installation wave energy monitoring). • NIMS (though 2016) (Dr. John Horne, University of Washington). In cooperation with PNNL, develop and test algorithms for real-time detection of biomass properties and individual target trajectories. |
| Candidate project(s) | <ul style="list-style-type: none"> • Development of automated detection and acoustic deterrent systems for around tidal devices. Possible lead: SMRU. This could possibly be undertaken in collaboration with work for ORJIP Offshore Wind or aquaculture funded work. • Extension/expansion of monitoring at Ramsey Sound to further test the capability of collision detection technologies • Deployment and testing of ‘integrated package’ at EMEC for example SME deployment at EMEC in 2016 • “Cooperative target” testing with objects of known mass, speed, and position to test capabilities of collision monitoring systems. Prototype drifter “swarm” in early development at NNMREC. Dr Brian Polagye (University of Washington) • Exploitation of sensors deployed on TEL DeltaStream turbine to analyse signals produced by ‘normal’ turbulence and establish a noise threshold. Use of Swansea BEMT software to predict levels of signal created by a collision and to determine if collision is significant and could be identified in the signal. Possible lead: Tidal Energy Limited/ Swansea University |

4.1.2 Underwater noise

| Project B.1 | Establishment of an acoustic ‘evidence base’ for operational devices and arrays |
|-------------|--|
| Aim | To ensure access to the best available data and information regarding underwater noise and marine energy projects for regulators, advisors, developers and researchers. |
| Objective | <p>An underwater noise database was created through a NERC KE project which aims to improve knowledge of underwater noise emitted by marine renewable devices around the coast of the UK to ultimately improve noise assessments, comparability of acoustic data and sound propagation models.</p> <p>This database needs to be maintained and hosted in such a way that maximises its future use in research and project development/consenting activities.</p> |
| Required | <ul style="list-style-type: none"> • Well maintained and accessible database to improve knowledge of underwater noise emitted by |

| Project B.1 | Establishment of an acoustic 'evidence base' for operational devices and arrays |
|---|---|
| outputs | marine renewable devices and associated infrastructure |
| Location | <ul style="list-style-type: none"> N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> None identified |
| Candidate project(s) | <ul style="list-style-type: none"> None identified |
| Recommended actions | <ul style="list-style-type: none"> Facilitate discussions to ensure that database is maintained and accessible to all (ORJIP Ocean Energy) |

| Project B.2 | Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays |
|---|---|
| Aim | To inform assessment of potential impacts of operational noise from demonstration and commercial scale arrays on key species |
| Objective | <p>There is currently broad agreement that the operation of single tidal turbines and small arrays will not result in significant effects on key species as a result of underwater noise. Concern remains that there is not sufficient evidence to rule out potentially significant effects from the operational of commercial scale arrays.</p> <p>The development of a robust noise propagation model, in parallel with gathering and sharing acoustic monitoring data from single machines, will enable developers to predict the acoustic profiles of arrays. This information can then be used to inform commercial scale EIA/HRA and will determine the need for any future baseline or post-consent monitoring studies.</p> <p>It will be important to consider how tidal flow and sea state might affect noise propagation and turbine noise modelling.</p> |
| Required outputs | <ul style="list-style-type: none"> Establishment of agreed approaches to modelling noise impacts from turbine operation including, potentially, validation of methods used in EIAs. Understanding of how operational noise changes when scaling up from single devices to arrays. Comparison of available propagation models Explanation of the models and their outputs to make them more user-friendly Explain how the outputs of the models translate into the impact assessments for different species to make it clear for regulators and advisors Explain how the outputs of the models translate into impact assessments for defence submarine navigational interests |
| Location | <ul style="list-style-type: none"> N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> EMEC project which looked at monitoring of noise across the different projects at their sites and what was learnt/what worked well. EMEC's regulator's guide to underwater noise funded by NERC TCE and MS guidance on underwater noise SNH proposal for underwater impact assessment on hold at the moment – they have submitted proposals for a project costing around £20-30k which would feed into one element of the underwater noise models Monitoring of noise outputs at Pelamis devices by Heriot-Watt – SNH funded SAMS/Loughborough project to investigate the effects of flow speed on noise propagation – DECC funded |
| Candidate project(s) | <ul style="list-style-type: none"> A review of the different approaches to noise modelling at consented W&T projects around the UK. This would need to be undertaken by an independent academic expert |

4.1.3 Displacement

| Project C.1 | Development of an agreed approach to assessing the potential effects and consequences of displacement from wave and tidal arrays |
|---|---|
| Aim | <ul style="list-style-type: none"> To determine whether or not displacement is an issue for the wave and tidal industries and if so, to determine if displacement is likely to be a potential issue at the cumulative and larger commercial scales To identify any input parameters that require improvement in understanding – this could identify data gaps/research needs and may help to determine what needs to be modelled. To help determine the need for/scope of any further research |
| Objective | At present, wave and tidal developers are required to consider the potential effects of displacement on marine birds, mammals and fish in relation to first arrays. However, it is essential at this time to consider whether or not displacement from wave and tidal arrays is ever likely to result in a biologically significant population effect. |
| Required outputs | <ul style="list-style-type: none"> Review of models currently used to estimate displacement e.g. PcoD, PVA, CEH displacement effects model (regarding consequences of displacement in birds for Forth and Tay offshore wind farms) Investigation into whether these models can be refined for use in wave and tidal industries |
| Location | N/A |
| Recently completed project(s) | <ul style="list-style-type: none"> Hebridean Marine Energy Futures project (awaiting publication) |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> Joint SNCB Displacement Advice Note. Advice on how to present assessment information on the extent and potential consequences of seabird displacement from Offshore Wind Farm (OWF) developments. Guidance completed Nov 2015, with expectation of release early in 2016. Though focused on offshore windfarms, many of the principles will be equally applicable to wave and tide. Contact: Glen Tyler (SNH) (Glen.tyler@snh.gov.uk). Marine Scotland – PVA project – out to tender Marine Scotland – Post-consent monitoring – offshore wind – power analysis study – out to tender Review of EMEC monitoring data by CREEM and EMEC TURNKEY Activity 6 aims to increase understanding of the possible interactions between fish and marine renewable energy developments, http://www.turnkeyproject.eu/, July 2013 to September 2015, (barbara.bremner@uhi.ac.uk). |
| Candidate project(s) | <ul style="list-style-type: none"> A review of existing approaches/models (e.g. those used by offshore wind industry) to investigate the consequences of displacement and refinement of these models for use in wave and tidal industries. Possible leads would be SMRU (marine mammals) and Centre for Ecology and Hydrology (CEH) (birds) |

4.1.4 Socio-economics

| Project D.1 | Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |
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| Aim | In line with Scottish and Welsh government policies to maximise the benefits from marine energy for the local and wider supply chain, various host communities and local/community investors who provide the backbone of support, and the key to future opportunities for the marine energy sector |
| Objectives | <ul style="list-style-type: none"> To better and fully understand the social and economic relationships linked to marine energy. To learn from the experience of the last 20 years of marine energy activity to promote proven mechanisms and find better approaches to engagement and collaboration between government, wider industry, local industry and communities. To explore more appropriate ways of planning, investing, working and sharing in the opportunities and challenges associated with marine energy. To create a better balance between the investigation, management, development and protection of social, economic, ecological and cultural assets associated with prospective marine energy |

| Project D.1 | Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |
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| | <p>production areas.</p> <ul style="list-style-type: none"> To ensure that wherever possible marine energy develops along with and alongside the other sectors with which it shares space, assets and opportunities. |
| Required outputs | <ul style="list-style-type: none"> To ensure that socio-economic studies and initiatives consider all stakeholders: technology inventors and innovators, larger industrials, utilities, other local and wider supply chain companies, academic institutions, government, agencies, other sea and land users, energy customers, near neighbours and associated communities To model the full social, economic, ecological and cultural life cycle of marine energy projects on a geographically sensitive basis. To better understand and manage the capacity, capabilities, aspirations, limitations and sustainable development potential of stakeholders in the marine energy sector. To better understand, develop and promote sustainable roles that all stakeholders can play in the future marine energy, and wider energy sector. To ensure that approaches to managing socio-economic issues are consistent with the needs of the appropriate regulatory, permitting and planning processes and that they focus upon future rather than past aspirations, needs and requirements. A methodology for social impact assessment that is qualitative Guide on what to include in an assessment – what do the regulators/local authorities actually need Stakeholder map (as long as beneficial and not just stating the obvious) |
| Location | <p>Learn from communities already associated with marine energy e.g. Orkney, Islay, Strangford, Cornwall, Isle of Wight, Cromarty Firth, Caithness & Sutherland, Shetland, Western Isles, Rathlin, S Wales, Anglesey, etc.</p> <p>Engage with all levels of stakeholders</p> |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> TCE report on socio-economic methodology and baseline for PFOW W&T developments TCE report on socio-economic methodology and baseline for W&T developments WES project on value of wave industry to Scotland MS assessment on socio-economics in different communities is currently being undertaken. TCE is feeding into it through Mike Cowling. Title is along the lines of “A two-way conversation with the people of Scotland on the Social Impact of offshore renewables” MS Community benefits report – led by onshore wind, currently in progress MSP work on socio-economic issues Human Dimensions of Tidal Energy (until August 2016) Dr. Stacia Dreyer. Case study comparison of attitudes towards current energy development in urban (Washington, US) and rural (Alaska, US) communities. Development of guidance for undertaking social impact assessment – Marine Scotland Development of guidance for undertaking economic impact assessment – Marine Scotland |
| Candidate project(s) | <ul style="list-style-type: none"> Guidance on how socio-economic issues should be addressed in EIAs and other regulatory and planning processes. Establish a generic socio-economic stakeholder map for the marine sector. Examination of the future roles and responsibilities for stakeholders in the marine energy sector. Approaches to characterising socio-economic receptors in the marine energy sector. |

4.1.5 General

| Project E.1 | Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines |
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| Aim | To gather data to help understand what effects on behaviour, if any, the presence and operation of devices and arrays may have on key species. |
| Objective | Strategic monitoring studies around single turbines and first arrays have the potential to increase understanding of behaviour of key species around operational tidal turbines and associated infrastructure. This evidence will help establish the need for future baseline characterisation surveys, inform future EIA/HRA and the need for any post-consent mitigation and monitoring. |
| Required outputs | <ul style="list-style-type: none"> • Better understanding of the potential effects of tidal energy projects to inform EIA/HRA. • Reduced uncertainty and a collective evidence base to help streamline future consenting processes and will help ensure that all project level requirements (baseline studies and post-consent mitigation and monitoring measures) are proportionate. • Review of existing data and information e.g. EMEC developer video monitoring |
| Location | TBC |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • Scottish Government Demonstrator Project at Meygen • Monitoring undertaken around tidal turbines including those deployed at EMEC, MCT at Strangford Lough, ORPC (USA), OpenHydro (Canada), Verdant Power (USA) • Monitoring undertaken around wave devices to date including those deployed at EMEC • Monitoring planned including MeyGen and TEL (Ramsey Sound), OpenHydro (France and Canada), FORCE (Canada) • Strangford Lough: the effect of an operating tidal turbine on Harbour seal movements. SMRU. Via DECC SEA site • Small-scale habitat use (rather than merely abundance) of renewable energy sites by mobile marine species (fish, seabirds, marine mammals); including Hebridean Marine Energy Futures (HMEF) project report, SNH/MS-funded work by SMRU, NERC RESPONSE project report • Knowledge on temporal and geographical distribution of marine animals at MRE sites (near and far field) Near field: Broudic, Tidal Energy Ltd , DeltaStream Demonstrator project, Use of PAM and AAS to monitor behavioural response of a marine mammals in close proximity of an operating turbine • SEACAMS II (planned): Investigation of Marine mammals behaviour in close proximity of an operating turbine • Understanding the impact of arrays and tidal range projects on the distribution of prey such as aggregation around structures and displacement. If tidal stream turbines act as fish aggregating devices, will this lead to more collisions with fish predators (birds and mammals). Predator prey interactions at a tidal stream site – FLOWBEC (EMEC). In press • Active sonar monitoring around Seagen and Minesto device in Strangford Lough to investigate behavioural impacts on birds and marine mammals • Ecology of black guillemots in relation to marine protected areas and marine renewable energy developments, October 2015-April 2019 (MASTS PhD) • Advanced Telemetry and Bio-logging for Investigating Grey Seal Interactions with Marine Renewable Energy Installations, January 2016 to January 2019 (PhD – University of Swansea KESS programme/NRW). Supervised by Dr Tom Stringell (NRW) and Dr James Bull, Dr Luca Borga and Prof Rory Wilson (University of Swansea). |
| Candidate project(s) | <ul style="list-style-type: none"> • Deployment of FLOWBEC or EMEC’s Integrated Environmental Monitoring Platform at existing sites e.g. EMEC, MeyGen (Possible funders – Scottish Enterprise/SDI/DECC SEA programme) • Extension/expansion of TEL monitoring programme in Ramsey Sound • SME deployment at EMEC in 2016 • Potential for new instrumentation and/or algorithms to be implemented by third parties during the Intelligent Adaptable Monitoring Package (Iamp) deployments planned for late 2016 off the Oregon Coast (US, pre-installation wave energy monitoring) and early 2017 at the Wave Energy Test Site (US, post-installation wave energy monitoring). |
| Recommended | <ul style="list-style-type: none"> • Investigate opportunities or mechanisms for collaborative data sharing or strategic monitoring |

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| Project E.1 | Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines |
| actions | across test sites, demo zones and projects (ORJIP Ocean Energy and Project Managers) |

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| Project E.2 | Development of mitigation measures for identified and potential impacts of wave and tidal developments |
| Aim | To develop a 'toolbox' of possible mitigation measures for use in EIA/HRA and the development of Project Environmental Management Plans |
| Objectives | <p>The development of an industry Toolbox which lists and describes mitigation measures that can be implemented to reduce or remove identified and possible impacts that may result from tidal energy developments could be used in the development of project specific Project Environmental Management Plans. The creation and maintenance of a common platform, or Toolbox, would ensure that all developers and regulators have access to the best available information regarding possible mitigation measures. It is important that this is informed by a review of the effectiveness of each mitigation measure from environmental monitoring reports and other research.</p> <p>It is possible that new or adapted mitigation measures may be required to reduce or remove certain potential impacts. Any requirement for new and adapted measures will be determined through the deployment and monitoring of single machines and first arrays.</p> |
| Required outputs | <ul style="list-style-type: none"> • 'Toolbox' of existing mitigation measures for wave, tidal stream and tidal range • Development of novel mitigation measures • Review of the effectiveness/success of mitigation measures • Review of the transferability of mitigation measures between different developments • Toolbox with industry standard mitigation measures that can be implemented/adapted at a project level |
| Location | <ul style="list-style-type: none"> • N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • All project EIAs and HRAs • ORJIP Review of Acoustic Deterrent Devices and Marine Mammal Mitigation for Offshore Wind Farms (SMRU Marine and Xodus) Phase 2 (stage 1 and stage 2): Exploring the possibility of using ADDs as a 'replacement' for MMO/PAM mitigation. Although the focus of the work has been on offshore wind, some of the principles might apply to ocean energy. |
| Candidate project(s) | <ul style="list-style-type: none"> • Trial of acoustic deterrent devices (ADDs) at the TEL Ramsey Sound site |

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| Project E.3 | Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays |
| Aim | To support the development of technologies and agreed approaches for detecting and identifying wildlife, monitoring wildlife behaviour and interactions with machines and support structures in high energy environments. |
| Objective | <p>The use of monitoring systems which have already been developed has not been exploited optimally because of lack of funding. There are also significant challenges regarding use of existing technology which currently undermine our ability to monitor at the scale of arrays, and over timescales needed to obtain useful data. Hence, powering up, marination and ease of deployment/recovery are all considerations which need to be urgently addressed, as is the potential to deploy monitoring technology in tandem with devices/foundations.</p> <p>It is also clear that some of the existing technologies do not collect data at appropriate spatial scales to be of use, and development of appropriate software/data transfer systems often lags behind the development of the hardware. Development of GPS tagging technology has proceeded apace and there is much to gain from use of telemetry and tagging at array deployment sites.</p> |

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| Project E.3 | Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays |
| | Further development of suitable instrumentation and methodologies are clearly required to enable strategic monitoring studies to proceed. Strategic monitoring studies around single turbines and first arrays have the potential to provide evidence to reduce uncertainty around collision risk, evasion and avoidance behaviour. This evidence will help determine whether or not collision is every likely to be an issue for marine mammals; establishing the need for future baseline characterisation surveys and post-consent mitigation and monitoring. |
| Required outputs | <p>Critique of the capabilities of existing technologies including the suitability, quality, reliability, durability, limitations, etc. for use in high energy marine environments combined with an analysis of the specific development/innovation needs to allowing detection and monitoring at the scale of arrays.</p> <p>Development/trialling of suitable cost-effective instruments and methodologies for use in high energy environments to monitor wildlife behaviour and to detect and quantify incidence of any collisions during operation of single test devices and first arrays.</p> <p>Development of cost effective monitoring systems to gather behavioural data to inform EIA/HRA. Increased understanding and an evidence base to reduce future requirements and streamline the consenting process.</p> |
| Location | Test sites and first arrays |
| Recently completed project(s) | <ul style="list-style-type: none"> SNH and MS funded report (SNH, 2015), Development of a monitoring protocol for assessing the use of seal haul-out sites in the Sound of Islay. Available at: http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=2387 |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> FLOWBEC platform, MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate SMRU/NERC/MREKE funded project to develop self-contained buoy tracking system (report due soon) Monitoring at Strangford Lough (MCT and Minesto), Ramsey Sound (TEL) Advanced Telemetry and Bio-logging for Investigating Grey Seal Interactions with Marine Renewable Energy Installations, January 2016 to January 2019 (PhD – University of Swansea KESS programme/NRW). Supervised by Dr Tom Stringell (NRW) and Dr James Bull, Dr Luca Borga and Prof Rory Wilson (University of Swansea). ORE Catapult Tidal Blade Collision Sensor (report due Q1 2016). Censis, with project funding contributions from NERC and SNH is delivering a study investigating the feasibility of adapting and developing existing sensor technology to detect final moments before impact and blade damage assessment. Insights will be made publically available ORE Catapult is working with PML and others to develop a Biofoul map of UK wave & tidal sites and looking at current Biofoul sensor technology |
| Candidate project(s) | <ul style="list-style-type: none"> Deployment of FLOWBEC or EMEC’s Integrated Environmental Monitoring Platform at existing sites e.g. EMEC, MeyGen (Possible funders – Scottish Enterprise/SDI/DECC SEA programme) Extension/expansion of TEL monitoring programme in Ramsey Sound SME deployment at EMEC in 2016 Potential for new instrumentation and/or algorithms to be implemented by third parties during the Intelligent Adaptable Monitoring Package (Iamp) deployments planned for late 2016 off the Oregon Coast (US, pre-installation wave energy monitoring) and early 2017 at the Wave Energy Test Site (US, post-installation wave energy monitoring). |
| Project E.4 | Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal current projects |
| Aim | To improve understanding of population level impacts and develop methods to assess the significance of population level impacts for protected mobile species to improve confidence in EIA/HRA for commercial scale projects and to inform project specific monitoring requirements. |
| Objectives | It is important to understand potential project specific and cumulative effects on populations of key species in order to inform EIA/HRA. There is uncertainty as to the level of impact that may result |

| Project E.4 | Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal current projects |
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| | <p>in a significant population level effect for protected species. This has resulted in a precautionary approach being applied to planned arrays requiring developers to undertake extensive baseline survey work to inform EIA/HRA. This has also resulted in a number of developers being required to implement mitigation and monitoring measures that may be disproportionate to the actual risks posed by developments.</p> <p>Confidence in EIA/HRA would be improved by establishing thresholds of acceptable change to mobile species populations by developing methodologies and tools for setting/allocating thresholds for features across multiple projects or in combination with other impacts. Reduced uncertainty around population level effects will help streamline future consenting process and help ensure that project level data gathering requirements are proportionate to the potential risks posed by the development.</p> |
| Required outputs | <ul style="list-style-type: none"> • Clarification required on how data is used by Regulators • Identify and prioritise impacts that have the potential to result in population level effects • Focus on species that are at risk/vulnerable • Establish the limits of acceptable impact under the terms of the Habitats Regulations for both European Protected Species and qualifying species of SACs and SPAs. • Develop a modelling and management framework appropriate for assessing the risks. Link results to the management of potential impacts on Favourable Conservation Status of protected sites/species. Model(s) to understand possible population level impacts • Methodologies for setting/allocating thresholds – Level of acceptability – better definition required. • Guidance on the application of mammal management units to EIA / HRA processes. |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • University of Aberdeen involvement in EPSRC EcoWatt project March 2015 to February 2017 • Field investigations of early migration behaviour of salmon smolts in Scottish nearshore waters planned for 2016. Environmental Research Institute, North Highland College |
| Candidate project(s) | <ul style="list-style-type: none"> • Review of different models that are currently being used to assess population level effects e.g. PcoD, PBR. |

| Project E.5 | Review and dissemination of findings of environmental monitoring studies |
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| Aim | To provide regulators, industry and stakeholders with the best available information regarding the potential environmental impacts of wave and tidal developments |
| Objectives | <p>To ensure that the best available information and data is available to regulators, agencies, stakeholders, developers and researchers to inform; marine planning and site selection, EIA/HRA, the development of Project Environmental Management Plans and future industry wide research plans.</p> <p>It is essential that data and information generated through international research and monitoring is considered/disseminated at a UK and project level and that it is used to inform policy and project level decisions at the earliest opportunity, to shrink the current gap between science and policy/decision making.</p> |
| Required outputs | <ul style="list-style-type: none"> • Formal mechanism to share data and experience across test sites, demo zones and projects, including exploration of the value of 'cluster' approaches to gather data to inform consent applications for multiple projects. • Regular focused knowledge exchange workshops • Maintained online database/library and notification system • Position papers on key issues based upon the best available information • Wide dissemination of all outputs and resources including international engagement and collaboration • Online platforms for information sharing and discussion around key consenting issues, lessons |

| Project E.5 | Review and dissemination of findings of environmental monitoring studies |
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| | <p>learnt etc.</p> <ul style="list-style-type: none"> • Effective transfer of data and information from 'science to policy' from the ocean energy sector and other industries where relevant |
| Location | N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • OES Annex IV (including the Tethys database, webinars, expert forums and State of the Science Report led by the Pacific Northwest National Laboratory) |
| Candidate project(s) | <ul style="list-style-type: none"> • Continuation and expansion of OES Annex IV |
| Recommended actions | <ul style="list-style-type: none"> • Facilitate discussion and collaboration between database managers e.g. Wave and Tidal Knowledge Network, Tethys (ORJIP Ocean Energy) • Establish a working group or formal mechanism for sharing data and experience between test sites, demo zones and projects (ORJIP Ocean Energy) • Facilitate and encourage communication of new data and information from research to policy (All) |

4.1.6 Regulatory

| Project F.1 | Review of PBR approach to regulation including consideration of alternatives |
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| Aim | To review the existing PBR based approach to consenting marine energy projects in the UK and to identify and consider alternatives |
| Objectives | <p>At present, there is an assumption that collisions will occur between sensitive species and that all collisions would result in mortality. This, coupled with the robustness of PBR models, makes it difficult to provide a realistic quantitative assessment of the potential impacts of wave and tidal energy developments, making future projects difficult to consent.</p> <p>This project will help to identify possible alternative approaches/improvements for high priority species e.g. harbour seal and will help identify further research priorities.</p> |
| Required outputs | <ul style="list-style-type: none"> • Identify possible alternatives that could be adopted given the immediacy of the issue • Review legislation – what is actually required? Ultra precautionary approach is limiting understanding of the issue despite the impact being uncertain. • Development of monitoring programmes for consented projects to reduce uncertainty. Monitoring requirements around operational tidal devices should be clearly defined and public reporting of data e.g. Scottish demonstration Strategy at MeyGen – what duration of monitoring is required before next phase of development can commence? The requirements should be clearly defined. |
| Location | N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • Marine Scotland – Fine scale (1km x 1km) seal density mapping to update seal density maps for PFOW |
| Candidate project(s) | <ul style="list-style-type: none"> • A review of the use of PBR as a tool for assessing the significance of or thresholds for impacts on marine mammals within consenting processes. Note: NRW are considering commissioning this project pending availability of required resources (funds and staff time). Would be managed by Dr Tom Stringell, Senior Marine Mammal ecologist. |
| Recommended actions | <ul style="list-style-type: none"> • Feedback results from workshop on 'methods for assessing impacts on seal populations' on 3rd Feb 2016 (SNH and Marine Scotland) |

| Project F.2 | Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process |
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| Aim | To review and improve the existing approach to risk management within the consenting process so as to ensure that project specific requirements are proportionate to the potential risks posed by a specific development |
| Objectives | <p>At present, a precautionary approach to consenting has been applied to most tidal energy developments, particularly planned arrays. This has resulted in requirements for lengthy and expensive baseline studies which have significantly affected project timescales and development budgets. There is an apparent disconnect between such survey requirements and the ability of the data to help identify, assess and manage potential impacts specific to tidal energy developments. There is growing concern that by applying a precautionary approach, the level of scrutiny being placed on the sector is disproportionate to the potential risks posed by tidal energy projects.</p> <p>A number of tools, methods and processes for managing environmental risks associated with tidal energy developments have been developed in recent years. Further development and consolidation of these tools and methods could help establish a common and proportionate approach to risk management similar to that seen in other sectors e.g. oil and gas and aquaculture which could help streamline future consenting processes for commercial scale tidal energy projects.</p> |
| Required outputs | <ul style="list-style-type: none"> • Clarity and guidance regarding the consenting process and supporting information requirements for test sites and demonstration zones • A proportionate but robust approach to evidence gathering for test sites, demonstration zones and arrays which is clearly linked to identified sensitivities and impact pathways |
| Location | N/A |
| Recently completed project(s) | <ul style="list-style-type: none"> • NRW Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales (July 2015) (http://www.naturalresources.wales/our-evidence-and-reports/guidance-to-inform-marine-mammal-site-characterisation-requirements-at-wave-and-tidal-stream-energy-sites-in-wales/?lang=en.) NRW commissioned report carried out by SMRU Consulting. This project developed a framework for assessing risk to marine mammals from wave and tidal stream developments and provides guidance on how to tailor surveys to provide better information for impact assessments. |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • Horizon 2020 RiCORE Work package 3 – Survey, Deploy and Monitor. This work package concerns the feasibility of a rollout of the Survey Deploy and Monitor approach to consenting across the EU as well as other forms of risk-based and adaptive management. See http://ricore-project.eu Scottish Government – Review of the potential impacts of wave and tidal energy developments on Scotland’s marine ecological environment |
| Candidate project(s) | <ul style="list-style-type: none"> • Review of existing consents to determine how baseline survey data was used to inform the decision making process with a view to establishing good practice/principles |
| Recommended actions | <ul style="list-style-type: none"> • Provide clarity on the consenting process for test sites and demonstration zones (regulators) • Provide guidance on corresponding data requirements to support consent applications (regulators and SNCBs) • Develop and refine risk based approaches to consenting (regulators) • Establish a formal mechanism to share data and experience across test sites, demo zones and projects (ORJIP Ocean Energy) and ensure that learning is translated into the development of agreed good practice within consenting processes. |

| Project F.3 | Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays |
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| Aim | To develop and agree a suitable approach for implementing a design envelope approach to EIA and HRA for wave and tidal arrays. |
| Objectives | Due to the nascent nature of the ocean energy sector, it is difficult for project developers to fully define proposals at the scoping and EIA stage to the standard that may be expected for more established (particularly onshore) sectors. In order to consent projects, regulators require sufficient information to fully understand the potential for any significant impacts to arise from a proposal. Given the current status of the energy extraction technologies and supporting infrastructure, there are also considerable benefits in retaining a degree of flexibility in a consent application. Conversely, |

| Project F.3 | Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays |
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| | <p>a design envelope which is too wide, can lead to unrealistic development scenarios and considerable difficulties in predicting and assessing potential impacts, particularly where cumulative and in-combination impacts are being considered.</p> <p>This topic was raised during a recent workshop held in Cardiff by The Crown Estate, Scottish Natural Heritage, Natural Resources Wales, Natural England and Welsh Government. Participants agreed that further support and guidance is required to ensure that project design envelopes can be defined in such a way that allows developers to retain a necessary degree of flexibility whilst meeting the requirements of regulators and stakeholders. This should consider the implications of the project design envelope through the whole consenting process from pre-application through consents to post-consent construction and operation.</p> |
| Required outputs | <ul style="list-style-type: none"> • An evidence base of projects already consented/developed to enable better definition of more realistic design envelopes in the future • Good practice guidance for defining project design envelopes for test sites, demonstration zones and arrays • Formal mechanisms to enhance shared learning from existing/consented projects and to translate this learning into the development of agreed good practice. • Industry glossary of agreed terminology |
| Location | N/A |
| Recently completed project(s) | <ul style="list-style-type: none"> • Findings of UK Demo Zone workshop held in Cardiff in July 2015 by The Crown Estate, Scottish Natural Heritage, Natural Resources Wales, Natural England and Welsh Government (Available at: http://www.thecrownestate.co.uk/media/501992/ei-uk-wave-and-tidal-demonstration-zones-workshop.pdf). |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • None identified at this time |
| Candidate project(s) | <ul style="list-style-type: none"> • Possible project by NRW⁵ - Developing principles and approaches to defining Project Design Envelopes for marine projects, using marine mammals and the Morlais north Anglesey tidal energy demonstration zone as a case study. (If the project goes ahead it would be completed by April 2016). This project will use marine mammals and the West Anglesey Demonstration Zone as a case study to explore the environmental issues, challenges and opportunities associated with defining flexible project design envelopes for multi-technology marine energy test sites and demonstration zones, with a view to further developing the good practice approaches and principles identified at the UK demo zone workshop held in Cardiff in July 2015. • Development of guidance and good practice for defining project design envelopes for demonstration zones and arrays including a review of experience and lessons learned from test sites and consented projects. |
| Recommended actions | <ul style="list-style-type: none"> • Organise and facilitate a workshop on project design envelopes to help inform guidance on best practice (ORJIP Ocean Energy with support from regulators and SNCBs) • Produce an Industry Glossary of Agreed Terminology to ensure common interpretation and use of key terms e.g. commercial array, demonstration zone, lease area, site, etc. (ORJIP Ocean Energy with support from regulators and SNCBs) |

⁵ Supported by Project Steering Group composed of Morlais, SEACAMS, NRW Operations, NRW Licensing

| Project F.4 | Development and agreement of methods/processes for developing Project Environmental Management Plans, incorporating mitigation measures and adaptive management strategies, for demonstration and commercial scale wave and tidal arrays |
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| Aim | To provide methods and procedures for developing PEMP for commercial scale, long terms wave and tidal array developments |
| Objectives | Project Environmental Management Plans have been developed for single device installations and small scale arrays. In order to move towards the planning for and consenting of commercial scale arrays, methods and procedures are required to help develop PEMP and adaptive management strategies to enable the development of commercial scale and long term PEMP for wave and tidal projects. |
| Required outputs | <ul style="list-style-type: none"> • Review of PEMP (or similar) development and reporting processes from other marine industries • Review of single device and demonstration array PEMP developed to date • Guidance/suite of tools for developing, consulting on and implanting project specific PEMP including; stakeholder engagement plan, reporting timescales and requirements, feedback mechanisms, etc. |
| Location | N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • MS is currently developing a PEMP template for offshore wind developments • EMEC Environmental Appraisal – guidance on PEMP development • EMEC Monitoring Advisory Group are looking at monitoring requirements • FORCE Adaptive Management Plan • OpenHydro Snowhomish PUD Adaptive Management Plan • Development Zone workshops • NSIPs process – development of Evidence Plans • Development of Offshore Wind PEMP templates by Marine Scotland • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Beth Scott and Benjamin Williamson KTP Associate |
| Recently completed project(s) | <ul style="list-style-type: none"> • Adaptive Management Plans for MCT (Strangford Lough), Anglesey Skerries and Swansea Bay Tidal Lagoon |
| Candidate project(s) | <ul style="list-style-type: none"> • Development of guidance for producing Project Environmental Management Plans |

| Project F.5 | An agreed approach to undertaking any HRA with regards to SACs for harbour porpoise is required |
|------------------|---|
| Aim | To determine HRA requirements for future wave and tidal project applications and any implications for existing sites and licenced developments |
| Objectives | <p>Due to requirements of the EU Habitats Directive (92/43/EEC), SNCBs are required to identify Special Areas of Conservation for harbour porpoise. There is currently uncertainty as to when sites currently under consideration in the UK will go to consultation, at which point they will need to be considered during HRA.</p> <p>Due to the wide ranging nature of harbour porpoise and current uncertainty regarding a number of perceived risks with marine energy projects, particularly collision risk with operational tidal turbines, it is difficult to ascertain what effect the designation of Special Areas of Conservation will have on proposed marine energy developments in the UK with regards to HRA. Furthermore, it is uncertain what will be required with regards to existing sites and consents.</p> <p>Guidance is required from SNCBs and Regulators to ensure that a consistent and proportionate approach is applied to HRA across the UK.</p> |
| Required outputs | <ul style="list-style-type: none"> • Guidance as to how any SACs for harbour porpoise should be considered during any necessary project specific HRA • Guidance as to the status of harbour porpoise outside any designated SAC i.e. European Protected Species • Guidance on the interpretation of Management Units and how they should be used in HRA and |

| | |
|---|---|
| Project F.5 | An agreed approach to undertaking any HRA with regards to SACs for harbour porpoise is required |
| | EIA |
| Location | N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • Management Papers currently being prepared by SNH • Guidance is currently being developed by Marine Scotland and SNH regarding this issue |
| Candidate project(s) | <ul style="list-style-type: none"> • Development of guidance on interpretation of Management Units and how they should be applied to EIA/HRA. Possible lead and funders: SNCBs. • As part of the exploration of issues surrounding the development of Conservation Objectives and management for the proposed new harbour porpoise SACs, the UK Statutory Nature Conservation Bodies are considering how disturbance might be assessed within HRA and in particular, how <i>significant</i> disturbance might be defined. There are no outputs which can be shared at this stage in the process, but outputs will be shared as appropriate. Although the focus of these considerations has been piling activity and acoustic disturbance, some of the principles are likely to also be relevant for wave and tidal stream projects. |

4.1.7 Shipping and navigation

| | |
|---|--|
| Project G.1 | Development of agreed methods/processes for assessing, mitigating and managing potential impacts on shipping and navigation |
| Aim | To develop agreed methods/processes for assessing, mitigating and managing potential impacts on shipping and navigation |
| Objectives | To develop agreed methods/processes for assessing, mitigating and managing potential impacts on shipping and navigation; particularly in relation to potential cumulative impacts around development clusters and strategic development areas. |
| Required outputs | <ul style="list-style-type: none"> • SANAP for key strategic development areas • Site suitability mapping tool that considers navigational safety |
| Location | N/A |
| Relevant projects currently planned or underway | <ul style="list-style-type: none"> • Strategic Area Navigation Appraisal (SANAP) for the Pentland Firth and Orkney Waters Strategic Area (Anatec) • NOREL guidance on under keel clearance |
| Candidate project(s) | <ul style="list-style-type: none"> • Strategic Area Navigation Appraisal (SANAP) for key development areas • Development of a navigational site suitability screening tool |

5 CONCLUSIONS AND NEXT STEPS

A number of high priority strategic research projects have been identified through wide ranging consultation with the ORJIP Ocean Energy Network and the Steering Group. This work built on previous efforts during which a broad consensus was reached between industry, regulators, stakeholders and the wider research community. ORJIP Ocean Energy, through the Secretariat, will continue to actively work to ensure progress in these high priority research areas through the following tasks:

- Wide distribution of the Forward Look and the objectives of ORJIP Ocean Energy
- Active engagement with the ORJIP Ocean Energy Network to identify relevant research planned and underway
- Active engagement with the ORJIP Ocean Energy Network to identify interested organisations and consortia to progress, lead and fund high priority strategic research projects to help meet the objectives of ORJIP Ocean Energy
- Active engagement with potential funding agencies to ensure that the research priorities of ORJIP Ocean Energy inform strategic decisions regarding future calls and opportunities
- Active engagement with existing research programmes to align objectives with those identified in the Forward Look
- Promotion of the programme objectives through the ORJIP Ocean Energy website – www.orjip.org.uk

At this time, ORJIP Ocean Energy would like to actively encourage Network participants to express their interest in any of the high priority strategic research projects identified. Whilst ORJIP Ocean Energy will not directly fund the projects, the Secretariat will strive to support and facilitate interested organisations or consortia in their endeavours to help meet the objectives associated with the high priority strategic research projects outlined in this Forward Look. Any updates regarding recently completed, ongoing or planned research relevant to these research topics would be most welcome at any time.

Similarly, should Network participants be planning to pursue any of the other research areas identified in the Forward Look i.e. those identified as 'medium' or 'low' priorities for the wave and tidal sectors, ORJIP Ocean Energy would welcome any updates and may be able to provide support to organisations/consortia in the planning of research projects and dissemination of results.

The Forward Look will be updated again in May 2016.



6 APPENDICES

APPENDIX A STEERING GROUP AND NETWORK

The following table presents the organisations and companies that have agreed to participate in the ORJIP Ocean Energy Steering Group and Network respectively.

| Steering Group/Network | Category | Organisation |
|------------------------|-------------------------|---------------------------------------|
| Steering group | Funding | ORE Catapult |
| Steering group | Regulator | DECC |
| Steering group | Regulator | Defra |
| Steering group | Regulator | DETI NI |
| Steering group | Regulator | DOE NI - Regulatory (Marine Division) |
| Steering group | Regulator | Marine Scotland – Consents |
| Steering group | Regulator | Marine Scotland – Science |
| Steering group | Regulator | Marine Management Organisation (MMO) |
| Steering group | Regulator | Natural Resources Wales – Advisory |
| Steering group | SNCB | Scottish Natural Heritage |
| Steering group | Sponsor | Marine Scotland |
| Steering group | Sponsor | The Crown Estate |
| Steering group | Sponsor | Welsh Government |
| Steering group | Wave developer | Albatern |
| Steering group | Test facility/demo zone | EMEC |
| Steering group | Tidal current developer | DP Energy |
| Steering group | Tidal current developer | Meygen |
| Steering group | Tidal current developer | OpenHydro |
| Steering group | Tidal range developer | Tidal Lagoon Power |
| Network | Academic | Low Carbon Research Institute |
| Network | Academic | SEACAMS |
| Network | Academic | MASTS |
| Network | Conservation | Marine Conservation Society |
| Network | Conservation | Whale and Dolphin Conservation |
| Network | Consultant | ABPmer |
| Network | Consultant | Aquatera |
| Network | Consultant | MacArthur Green |
| Network | Consultant | Gardline Environmental Ltd |
| Network | Consultant | Marine Ecological Services (MES) Ltd |
| Network | Consultant | MarineSpace |
| Network | Consultant | Royal HaskoningDHV |
| Network | Consultant | RPS Energy |
| Network | Consultant | SMRU Consulting |

| Steering Group/Network | Category | Organisation |
|------------------------|-------------------------|--|
| Network | Consultant | Source Low Carbon |
| Network | Consultant | Xodus Group |
| Network | Funding | Highlands and Islands Enterprise (HIE) |
| Network | General | NERC Knowledge Exchange Fellow/SAMS |
| Network | General | ORJIP Offshore Wind |
| Network | General | Offshore Renewables Development Programme |
| Network | General | The Carbon Trust |
| Network | Industry | Marine Energy Pembrokeshire (MEP) |
| Network | Industry | Regen SW |
| Network | Industry | Scottish Renewables |
| Network | International | Acadia University |
| Network | International | EMERA |
| Network | International | Fundy Environmental Research Network (FERN) |
| Network | International | Marine Renewable Energy Ireland (MaREI) |
| Network | International | National Northwest Marine Renewable Energy Centre (NNMREC) |
| Network | International | Oregon Wave Energy Trust (OWET) |
| Network | International | Pacific Northwest National Laboratory (PNNL) – Annex IV |
| Network | International | SEACORE |
| Network | SNCB | Natural England |
| Network | Test facility/demo zone | FaBTest (Falmouth Bay Test site) |
| Network | Test facility/demo zone | Morlais Energy |
| Network | Test facility/demo zone | Wave Hub |
| Network | Tidal current developer | Manx Tidal Energy |
| Network | Tidal current developer | Nova Innovation |
| Network | Tidal current developer | Ocean Renewable Power Company (ORPC) |
| Network | Tidal current developer | SCHOTTEL Hydro |
| Network | Tidal current developer | Scotrenewables |
| Network | Tidal current developer | Sustainable Marine Energy (SME) |
| Network | Tidal current developer | Tidal Energy Ltd (TEL) |
| Network | Wave developer | Carnegie Wave Energy |
| Network | Wave developer | Marine Power Systems |

APPENDIX B ISSUES/RISKS NO LONGER CONSIDERED TO BE KEY STRATEGIC CONSENTING ISSUES – WAVE AND TIDAL ENERGY

Appendix table B.1 List of consenting issues/risks no longer considered to be key strategic consenting issues – wave and tidal energy

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|-------------------------------|--|------------------------------------|-------------------------------|------------------------------------|-------------------------------|--|
| Ecological environment | | | | | | |
| Underwater noise | Agreed approaches for measuring ambient noise in high energy environments are required | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | Not considered to be a key strategic consenting issue. This has been addressed by work undertaken e.g. by The National Physical Laboratory (NPL). It is now important that the guidance produced is adopted by regulators and statutory advisors, and implemented by developers and researchers. |
| Underwater noise | Agreed approaches for measuring noise from operational devices and construction activities are required | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | Not considered to be a key strategic consenting issue. This has been addressed by work undertaken e.g. by NPL. It is now important that the guidance produced is adopted by regulators and statutory advisors and implemented by developers and researchers. |
| Underwater noise | Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on diving birds is incomplete | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This is not considered to be a key strategic consenting issue (assuming that piling is not used). |
| Underwater noise | Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on fish is incomplete | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | This is not considered to be a key strategic consenting issue (assuming that piling is not used). |
| Entanglement | Concern within the regulatory and advisory bodies that mooring lines pose an entanglement risk to marine mammals and large fish | Both | No, project specific | Demonstration and commercial | Yes | An SNH commissioned review of the potential for megafauna entanglement risk from marine energy developments concluded that moorings associated with marine renewable energy devices are unlikely to pose a major threat to cetaceans due to the size and mass of the moorings |

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|---|---|------------------------------------|-------------------------------|------------------------------------|-------------------------------|--|
| | | | | | | however there is a greater risk for large baleen whales due to their size and foraging habitats. ⁶ This is no longer considered to be key strategic consenting issue. |
| Seal injuries from vessel propellers | Lack of understanding around the possible cause of death to seals with 'corkscrew' injuries | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | There is strong evidence that predatory behaviour by grey seals, rather than ship propeller injuries, is likely to be the main cause of spiral seal deaths. ⁷ This evidence does not completely eliminate ship propellers, but it is now less likely they are a key factor. This is no longer considered to be a key strategic consenting issue specific to the wave and tidal sectors. |
| Reef effects | Potential for positive effects such as use of development sites as feeding and nursery areas for fish and use of structures as fish aggregation devices | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Reef effects | Indirect effects on predators including potential for increased foraging opportunities | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Introduction of non-native invasive species | An agreed approach is required in the use of guidance for MNNS to inform the development of Project Environmental Management Plans | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Entrapment | Potential risk of entrapment of marine mammals and basking sharks from machines and associated moorings or support structures | Both | No, technology specific | Demonstration and commercial | No | Not considered to be a key strategic consenting issue. |
| Barrier to movement | It is uncertain whether developments will cause a barrier to movement for marine mammals and | Both | No, site/project specific | Demonstration and commercial | No | Not considered to be a key strategic consenting issue. |

⁶ http://www.snh.org.uk/pdfs/publications/commissioned_reports/791.pdf

⁷ <http://www.smru.st-and.ac.uk/documents/2173.pdf>

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|--|---|------------------------------------|-------------------------------|------------------------------------|-------------------------------|---|
| | basking sharks | | | | | |
| Barrier to movement | It is uncertain whether developments will cause a barrier to movement for migratory fish | Both | No, site/project specific | Demonstration and commercial | No | Not considered to be a key strategic consenting issue. |
| Impacts on benthic communities | Direct loss of habitat and near field effects (e.g. scour, deposition) on protected or sensitive sub-littoral seabed communities | Both | No, site/project specific | Demonstration and commercial | No | Not considered to be a key strategic consenting issue. |
| Impacts on benthic communities | The potential wider or secondary effects on protected or sensitive sub-littoral seabed communities due to installation and operation of machines and associated moorings or support structures is poorly understood | Both | No, site/project specific | Commercial | No | Not considered to be a key strategic consenting issue. |
| Ecological effects due to changes in hydrographic properties | Effects on predator-prey capture rates due to changes in hydrodynamic properties as a result of presence and operation of machines | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Ecological effects due to changes in hydrographic properties | Effects on ecosystem functioning due to changes in hydrodynamic properties as a result of presence and operation of machines | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Human environment | | | | | | |
| Impacts on commercial fisheries | Further baseline inshore fisheries activity data to inform CIA (Cumulative Impact Assessment) | Both | No, site/project specific | Demonstration and commercial | Yes | This is not considered to be a key strategic consenting issue. Data is required at a project/site level to inform site selection and EIA. |
| Impacts on commercial fisheries | Lack of standard measures for mitigating potential impacts on commercial fisheries | Both | No, site/project specific | Demonstration and commercial | Yes | Not considered to be a key strategic consenting issue. Any mitigation measures would be entirely site and project specific. |
| Impacts on commercial fisheries | Lack of a standardised approach and guidance, specific to the sector, on effective engagement with the commercial fishing industry and local stakeholders | Both | Yes, relevant to all projects | Demonstration and commercial | Yes | Not considered to be a key strategic consenting issue. This is a site and project specific issue. There is sufficient existing guidance i.e. FLOWW. |

| Topic | EIA/HRA issue | Relevant to wave or tidal current? | Strategically relevant? | Commercial or demonstration scale? | Key issue in previous report? | Current key strategic consenting issue? |
|------------------------------------|---|------------------------------------|-------------------------------|------------------------------------|-------------------------------|---|
| Impacts on shipping and navigation | Further baseline data to inform cumulative aspects of Marine Navigational Impact Assessments | Both | No, site/project specific | Demonstration and commercial | Yes | This issue is considered to be site/project/regionally specific and not a key strategic consenting issue. |
| Impacts on tourism and recreation | Difficult to predict and assess potential impacts on tourism and recreation | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Carbon footprint | A standard approach for accurately calculating the full life cycle carbon footprint for wave and tidal arrays is required | Both | Yes, relevant to all projects | Commercial | No | Not considered to be a key strategic consenting issue. |
| Physical environment | | | | | | |
| Impacts on physical processes | Lack of baseline field data to inform hydrographic models | Both | No, site/project specific | Commercial | No | Not considered to be a key strategic consenting issue. |

APPENDIX C RESEARCH GAP ANALYSIS DATABASE

A summary of the research gap analysis database is provided in the following table. This summary includes all of the projects considered during the gap analysis i.e. high, medium and low priorities and provides the following information:

- List of research gaps in relation to each key consenting issue and risk identified during the project
- List of possible research projects that could address each research gap
- Results of the screening process implemented to identify the high priority strategic research projects that will form the focus of ORJIP Ocean Energy

NOTE: The following criteria were used to identify high priority strategic research projects:

| | |
|------------------------|---|
| High priority | Projects required in the immediate near-term that would benefit from a strategic approach and have the potential to address key consenting risks relevant to early array developments in line with the overarching aim of ORJIP Ocean Energy. |
| Medium priority | Projects that would benefit from a strategic approach that have the potential to address key consenting issues but are not considered to be short-term priorities for the wave and tidal sectors. |
| Low priority | Projects that may benefit from a strategic approach and have the potential to address aspects of key consenting issues. The need for these projects will be informed by the outcomes of other higher priority research projects. |

Please note that the following table is organised by ‘topic’ similar to Table 2.1 and high priority strategic projects are listed where relevant.

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|---|--|--|--|
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Behaviour of diving birds (including avoidance and evasion behaviour and the attraction of species) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for predatory species of birds | Further research/monitoring studies around single test devices and first demonstration arrays to gather information on the behaviour of marine birds around operating devices and to quantify avoidance rates for input in Collision Risk Modelling (CRM). Need to build evidence base to assess whether collision is likely to be an issue or not for diving birds. It is important that data on avoidance and behaviour is collated and organised in a systematic manner so that data collected can feed into the development of Collision Risk Models (CRMs). | High Project E.1 Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Behaviour of diving birds (including avoidance and evasion behaviour and the attraction of species) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for predatory species of birds | Disseminate and appraise findings of monitoring studies around single test devices to inform need for studies around demonstration arrays. A review of results as they become available will inform whether further monitoring is required. | High Project E.5 Review and dissemination of findings of environmental monitoring studies |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Behaviour of diving birds (including avoidance and evasion behaviour and the attraction of species) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for predatory species of birds | Further research to investigate probability of collisions occurring and factors affecting the likelihood of collision e.g. size of animal, swim speed, device speed, etc. | Medium |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Behaviour of diving birds (including avoidance and evasion behaviour and the attraction of species) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence • The extent to which devices, moorings and inter-array areas | <ul style="list-style-type: none"> • Laboratory based experimental research e.g. tank testing using animals or animal-sized objects to determine the proportion of individuals that are struck or otherwise injured • Hydrodynamic modelling • Computational Fluid Dynamics (CFD) | Medium |

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|---|--|--|---|
| | | may act as fish aggregation devices and therefore increase potential for collision risk for predatory species of birds | | |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Behaviour of diving birds (including avoidance and evasion behaviour and the attraction of species) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for predatory species of birds | Individual Based Models (IBMs) can be used to investigate emergent behaviours of groups and flocks of animals. This type of model has the flexibility that allows a range of environmental parameters to be included allowing the response of the simulated animals to the environment to be investigated. | Medium |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Assessing collision risk for diving birds. | Need an agreed approach for Collision Risk Modelling for diving bird species. | High Project A.4 Further development of collision risk models for marine mammals, fish and birds to inform EIA/HRA HOLD - SNH has contracted Bill Band to develop guidance on the 3 approaches most commonly used to date for underwater collision risk assessment (Band CRM, SRSL Encounter Rate Modelling (ERM) and RPS Exposure Time Modelling for Birds (ETM). This is due for publication in Feb 2016. A higher priority is to improve the input parameters for these CRMs |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | Use of tidal streams by diving birds: <ul style="list-style-type: none"> • Improved understanding of the functional importance of tidal stream areas • Improved understanding of the spatial and temporal patterns of site use of tidal stream areas (and | Further analysis of existing data to investigate species abundance and distribution against tidal cycle data to assess if key species are present in areas of greatest tidal flow to inform whether collision is likely to be a real issue (or not). | Medium |

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|--|---|---|---|
| | | <p>relative importance of these areas), and</p> <ul style="list-style-type: none"> Improved understanding of behaviour (e.g. diving depth, dive profiles, and the proportion of time spent at the operating depth of tidal turbines is key information) | | |
| Collision risk | 1.1 The nature of any potential interactions between diving birds and tidal turbines is uncertain | <p>Use of tidal streams by diving birds:</p> <ul style="list-style-type: none"> Improved understanding of the functional importance of tidal stream areas Improved understanding of the spatial and temporal patterns of site use of tidal stream areas (and relative importance of these areas), and Improved understanding of behaviour (e.g. diving depth, dive profiles, and the proportion of time spent at the operating depth of tidal turbines is key information) | Behavioural studies (including tagging) to look at diving behaviour to determine whether birds are at risk through their feeding ecology. Studies should focus on species identified by Furness et al. (2012) as being particularly sensitive to tidal energy developments. | Medium |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | <p>Behaviour of marine mammals and basking sharks (including avoidance and evasion behaviour and the attraction of inquisitive species e.g. bottlenose dolphin and minke whale) around tidal turbines to better understand the real level of risk of collisions including:</p> <ul style="list-style-type: none"> Probability of occurrence; The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for marine mammals | <p>Monitoring studies around single test devices and first demonstration arrays to gather information on the behaviour of marine mammals (cetaceans and seals) and basking sharks around operating devices and to quantify avoidance rates for input in Collision Risk Modelling.</p> <p>Need to build evidence base to assess whether collision is likely to be an issue or not for marine mammals and basking sharks. It is important that data on avoidance and behaviour is collated and organised in a systematic manner so that data collected can feed into the development of Collision Risk Models (CRMs).</p> | <p>High</p> <p>Project A.1 Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment</p> <p>Project E.1 Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines</p> |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking | Behaviour of marine mammals and basking sharks (including avoidance and evasion behaviour and the attraction of inquisitive species e.g. bottlenose dolphin and minke | Disseminate and appraise findings of monitoring studies around single test devices to inform need for studies around demonstration arrays. A review of results as they become available will inform whether | <p>High</p> <p>Project E.5 Review and dissemination of findings of</p> |

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|--|--|---|--|
| | sharks and tidal turbines is uncertain | whale) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence; • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for marine mammals | further monitoring is required. | environmental monitoring studies |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Behaviour of marine mammals and basking sharks (including avoidance and evasion behaviour and the attraction of inquisitive species e.g. bottlenose dolphin and minke whale) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence; • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for marine mammals | Further research to investigate probability of collision occurring and factors affecting the likelihood of collision e.g. size of animal, swim speed, device speed, responses to noise, etc. | High Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Behaviour of marine mammals and basking sharks (including avoidance and evasion behaviour and the attraction of inquisitive species e.g. bottlenose dolphin and minke whale) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence; • The extent to which devices, moorings and inter-array areas may act as fish aggregation devices and therefore increase potential for collision risk for marine mammals | <ul style="list-style-type: none"> • Laboratory based experimental research e.g. tank testing using animals or animal-sized objects to determine the proportion of individuals that are struck or otherwise injured • Hydrodynamic modelling • Computational Fluid Dynamics (CFD) • Individual Based Models (IBMs) can be used to investigate emergent behaviours of groups of animals. | High Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Assessing collision risk for marine mammals and basking sharks | Need an agreed approach for Collision Risk Modelling for marine mammals and basking sharks. | High Project A.4 Further development of collision risk models for marine mammals, fish and birds to inform |

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|--|--|---|---|
| | | | | EIA/HRA HOLD - SNH has contracted Bill Band to develop guidance on the 3 approaches most commonly used to date for underwater collision risk assessment (Band CRM, SRSL Encounter Rate Modelling (ERM) and RPS Exposure Time Modelling for Birds (ETM). This is due for publication in Feb 2016. A higher priority is to improve the input parameters for these CRMs |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Use of tidal stream by marine mammals and basking sharks: <ul style="list-style-type: none"> • Improved understanding of the functional importance of tidal stream areas • Improved understanding of the spatial and temporal patterns of site use of tidal stream areas (and relative importance of these areas), • Improved understanding of routes used for movement and migration; and, • Improved understanding of behaviour (e.g. diving depth, dive profiles, and the proportion of time spent at the operating depth of tidal turbines is key information) | Studies to determine how marine mammals and basking sharks are using high tidal energy environments and the relative importance of these areas compared to surrounding (presumably less energetic) environments. Need to gather data prior to devices being installed to assess where areas or times of key overlap exist. If species do not occur in the highest tidal energy areas or at times of highest flow/energy then that is obviously important. | Low - site specific |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | Use of tidal stream by marine mammals and basking sharks: <ul style="list-style-type: none"> • Improved understanding of the functional importance of tidal stream areas • Improved understanding of the spatial and temporal patterns of site use of tidal stream areas (and relative importance of these areas), | Further analysis of existing data (species abundance and distribution, seal tagging data) against tidal cycle data to assess if marine mammals are present in areas of greatest tidal flow to inform whether collision is likely to be a real issue (or not). | Low - site specific |

| Topic | Key Issue | Gaps identified | Research area | Priority |
|----------------|--|---|---|--|
| | | <ul style="list-style-type: none"> Improved understanding of routes used for movement and migration; and, Improved understanding of behaviour (e.g. diving depth, dive profiles, and the proportion of time spent at the operating depth of tidal turbines is key information) | | |
| Collision risk | 1.2 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain | <p>Use of tidal stream by marine mammals and basking sharks:</p> <ul style="list-style-type: none"> Improved understanding of the functional importance of tidal stream areas Improved understanding of the spatial and temporal patterns of site use of tidal stream areas (and relative importance of these areas), Improved understanding of routes used for movement and migration; and, Improved understanding of behaviour (e.g. diving depth, dive profiles, and the proportion of time spent at the operating depth of tidal turbines is key information) | Tagging work to help inform about behaviour of marine mammals in the water column (dive profiles, diving depth, swimming orientation of marine mammals and basking sharks in relation to tidal flow) for use in estimating collision risk but sample size issues present challenges. | Medium |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | <p>Behaviour of migratory fish (including avoidance and evasion behaviour) around tidal turbines to better understand the real level of risk of collisions including:</p> <ul style="list-style-type: none"> Probability of occurrence | Monitoring studies around single test devices and first demonstration arrays to gather information on the behaviour (e.g. aggregation or avoidance) of fish around operating devices and to quantify avoidance rates to help refine and validate (or otherwise) encounter risk models. Need to gather evidence to see whether collision is likely to be an issue or not for migratory fish. | Medium - site specific Project E.1 Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | <p>Behaviour of migratory fish (including avoidance and evasion behaviour) around tidal turbines to better understand the real level of risk of collisions including:</p> <ul style="list-style-type: none"> Probability of occurrence | Disseminate and appraise/review of data /findings of monitoring studies around single test devices to inform need for studies around demonstration arrays. A review of results as they become available will inform whether further monitoring is required. | High Project E.5 Review and dissemination of findings of environmental monitoring studies |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Behaviour of migratory fish (including avoidance and evasion behaviour) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence | Individual Based Models (IBMs) can be used to investigate emergent behaviours of groups of animals. | Low |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Behaviour of migratory fish (including avoidance and evasion behaviour) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence | Further research to investigate probability of collisions occurring and factors affecting the likelihood of collision e.g. size of animal, swim speed, device speed, etc. | Medium |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Behaviour of migratory fish (including avoidance and evasion behaviour) around tidal turbines to better understand the real level of risk of collisions including: <ul style="list-style-type: none"> • Probability of occurrence | Laboratory based experimental research e.g. tank testing using animals or animal-sized objects to determine the proportion of individuals that are struck or otherwise injured <ul style="list-style-type: none"> • In-water experimental research around operating turbines e.g. release of acoustically tagged fish to track movement past devices • Hydrodynamic modelling • Computational Fluid Dynamics (CFD) | Medium |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Assessing collision risk for migratory fish | Need an agreed approach for Collision Risk Modelling for migratory fish species. | High – Project A.4 Further development of collision risk models for marine mammals, fish and birds to inform EIA/HRA HOLD - SNH has contracted Bill Band to develop guidance on the 3 approaches most commonly used to date for underwater collision risk assessment (Band CRM, SRSL Encounter Rate Modelling (ERM) and RPS Exposure Time Modelling for Birds (ETM)). This is due for publication in Feb 2016. |
| Collision risk | 1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain | Use of tidal stream areas by migratory fish (research gaps identified in (Slaski <i>et al.</i> , 2013): <ul style="list-style-type: none"> • Migratory pathways / behaviour – to what extent are migratory | Monitoring studies to determine how migratory fish species are using high tidal energy environments and the relative importance of these areas compared to surrounding (presumably less energetic) environments. Need to gather data prior to devices | Low |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | | <p>salmonids likely to be geographically co-incident with the locations of wave and tidal energy projects</p> <ul style="list-style-type: none"> Swimming behaviour – if fish are geographically co-incident (in any significant numbers), to what extent are they likely to be physically co-incident. Swimming depth preference and avoidance capability appear to be the key questions Mode of transport in high current speeds – the degree to which passive transportation through areas of high energy takes place, and potential implications Encounter Effects – if some fish do make physical (or equivalent) contact with the wave or tidal energy device, what are the outcomes? | <p>being installed to assess where areas or times of key overlap exist. If species do not occur in the highest tidal energy areas or at times of highest flow/energy then that is obviously important.</p> | |
| Collision risk | 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds and fish and tidal turbines | Severity of injury should strike occur | <p>The consequences of collision with a turbine (or passage through a turbine in the case of fish) can be investigated using computer modelling or laboratory studies (e.g. tank testing) to study the effects of rotational speed of the blade, distance along blade, etc. on severity of injury for a range of turbine designs and species.</p> <p>NOTE: Based on preliminary flume and field studies, avoidance appears to be high and given the slow rate of rotation, impact on larger animals in the event strike should occur appears to be low. Though often compared, current evidence suggests that tidal turbine strike risk varies greatly from that of ship propellers and conventional hydropower turbines (US Dept. of Energy, 2012).</p> | <p>High</p> <p>Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals</p> |
| Collision risk | 1.4 There is uncertainty as to the possible physical consequences of potential collision events for marine mammals, diving birds | Severity of injury should strike occur | <p>Computational Fluid Dynamics (CFD) studies to ascertain if some species may have 'protection' from collision through entrainment. CFD models of turbines and turbine arrays could be used to predict the pressure fluctuations experienced by species as they pass close to turbines. These pressure traces</p> | <p>High</p> <p>Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with</p> |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | and fish and tidal turbines | | <p>can be used to find effects on key marine species and <i>their prey</i>.</p> <p>(Swansea University) Further study required on the potential causes of damage to fish. Recent work has highlighted the issue of rapid pressure change in the location of a TST as a potential threat. Establish a model to precisely predict the pressure fluctuations and intensities, and thus the effect on the wildlife, to determine the true risk and possible countermeasures if necessary.</p> | tidal turbines for marine mammals |
| Collision risk | 1.5 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 | Further development of suitable technologies/tools and methods for use in high energy tidal environments to monitor behaviour of wildlife in the vicinity of devices and support structures | <p>E.g. Development and trialling of technologies such as active sonar, underwater cameras, high resolution telemetry and other methods. Demonstrable capacity to track species movement.</p> <p>Development of cost-effective and appropriate long-term PAM and tracking. Static bottom-mounted hydrophone arrays</p> <p>Use of x-band radar, tagging systems or other methods to quantify the 3-dimensional movements of diving birds/fish to provide insight into the responses to tidal devices.</p> <p>Trial/test monitoring technologies (potentially at e.g. EMEC, WaveHub, FaBTest and other test sites) to inform improvements in technologies and cost reductions</p> | <p>High</p> <p>Project E.3 Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays</p> |
| Collision risk | 1.5 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 | Further development of suitable technologies/tools and methods for use in high energy tidal environments to detect and record actual collision events to quantify the incidence/frequency of collisions | | <p>High</p> <p>Project A.3 Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays</p> |
| Collision risk | 1.5 Further development of suitable instrumentation and methodologies for reducing collision risk, monitoring wildlife | <p>Further development of suitable technologies/tools and methods for use in high energy tidal environments to:</p> <ul style="list-style-type: none"> Monitor behaviour of wildlife in the vicinity of devices and support structures , and | Comparison of methods for monitoring especially as scaling up from single devices to arrays. | Medium |

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| | behaviour around devices and arrays and for detection of any collision events is required | <ul style="list-style-type: none"> • Detect and record actual collision events to quantify the incidence/frequency of collisions | | |
| Collision risk | 1.5 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 | <p>Further development of suitable technologies/tools and methods for use in high energy tidal environments to:</p> <ul style="list-style-type: none"> • Monitor behaviour of wildlife in the vicinity of devices and support structures , and • Detect and record actual collision events to quantify the incidence/frequency of collisions | Development of mitigation measures for novel wet renewable technologies may be required to ensure early deployments are compliant with the Habitats Regulations. While these can be developed on a project-specific basis, there would be merit in a more coordinated approach. | <p>High</p> <p>Project E.2 Development of mitigation measures for identified and potential impacts of wave and tidal developments</p> |
| Underwater noise | 2.1 Lack of available acoustic data from operational devices and arrays | There is a limited amount of available acoustic data from operational tidal devices and arrays. | Determination of acoustic signatures of devices to build an evidence base of operational noise levels. It is important that there is standardisation in measuring operational acoustic data so that data are comparable across projects. | <p>High</p> <p>Project B.3 Gather acoustic data around single operational machines</p> <p>HOLD</p> |
| Underwater noise | 2.1 Lack of available acoustic data from operational devices and arrays | There is a limited amount of available acoustic data from operational tidal devices and arrays. | <p>Acoustic signature data from operational devices and first arrays could be used to increase understanding of array effects and inform noise propagation models for commercial scale EIA and HRA (and CIA).</p> <p>Establishment of agreed approaches to modelling noise impacts from turbine operation including, potentially, validation of methods used in EIAs. Understanding of how operational noise changes when scaling up from single devices to arrays.</p> | <p>High</p> <p>Project B.2 Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays</p> |
| Underwater noise | 2.1 Lack of available acoustic data from operational devices and arrays | There is a limited amount of available acoustic data from operational tidal devices and arrays. | Data exchange and collaboration - establish a specific 'evidence base' regarding device-specific operational noise levels from ongoing work by developers (possibly alongside an expert forum) to ensure that data collected to meet licence conditions, and data from any publically funded research programme, is made available in the public domain to allow developers and researchers to learn from existing work. | <p>High</p> <p>Project B.1 Establishment of an acoustic 'evidence base' for operational devices and arrays</p> |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | The noise levels capable of causing impacts of differing significance (e.g. lethal, sub lethal, permanent, temporary) for marine mammal species of concern. | Research on the sensory ecology of marine mammals (cetaceans and seals): Expansion of range of species for which hearing capacities (i.e. audiograms) are available for key species in wave and tidal development areas. | Low |
| Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | Effects of operational noise (behavioural changes, disturbance and displacement effects) from underwater devices and construction activities on marine mammals. | Further research/monitoring studies around single test devices and first demonstration arrays to gather information on the behaviour of marine mammals around operating devices to gather evidence to see whether noise is likely to be an issue or not for marine mammals. | High Project E.1 Monitoring around operational tidal turbines and first arrays to gather information on the behaviour of diving birds, marine mammals, basking shark and migratory fish around operating tidal turbines |
| Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | Effects of operational noise (behavioural changes, disturbance and displacement effects) from underwater devices and construction activities on marine mammals. | Dose/response relationships are needed to understand the amplitude and frequencies of sounds that elicit reactions in animals of concern. Determine if device noise is audible to marine mammals to elicit avoidance behaviour (may be linked to potential collision risk). Investigate if there are acoustic barrier effects of operational devices/arrays. | Medium |
| Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | Effects of operational noise (behavioural changes, disturbance and displacement effects) from underwater devices and construction activities on marine mammals. | Measuring noise doses on individuals around devices will be useful and can be integrated into studies of behavioural responses. An approach using computational acoustic models, based on anatomical data might be preferable. | Medium |
| Underwater noise | 2.2 Knowledge regarding the possible effects of underwater noise from the construction and operation of arrays on marine mammals is incomplete | Effects of operational noise (behavioural changes, disturbance and displacement effects) from underwater devices and construction activities on marine mammals. | Further development of noise propagation models to inform assessment of the potential impacts of operational noise on receptors from demonstration and commercial scale arrays. | High Project B.2 Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| EMF | 3.1 Further data and information regarding the possible effects of EMF from transmission cables on fish would improve confidence in EIA and HRA | Understanding of the nature and significance, if any, of EMF effects upon potentially sensitive species groups (such as elasmobranchs and salmonids) remains limited. It is however, perceived by some as a potentially significant concern for salmonids especially, should it impact on migratory routes and return to home rivers. | Empirical studies determining influence (if any) of EMF on passage of salmonids and elasmobranchs. Focus at this stage may be best on cumulative effects. | <p>Low</p> <p>Recently published research by Marine Scotland Science found that in a study of behavioural responses of Atlantic salmon to mains frequency magnetic fields (MF) there were no observations of unusual behaviours in association with MF up to 95 μT http://www.gov.scot/Resource/0048/00484957.pdf</p> <p>Another study by Marine Scotland looking at the response of European eels <i>Anguilla anguilla</i> at the silver eel stage of their life-cycle to an AC MF of approximately 9.6 μT at a fine scale in a controlled laboratory setting found no evidence of a difference in movement due to the MF nor observations of startle or other obvious behavioural changes associated with the magnetic fields. http://www.gov.scot/Resource/0048/00484920.pdf</p> |
| Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | An agreed approach to assessing the potential effects of displacement from tidal arrays | Undertake a review of findings of offshore wind research into displacement and the assessment of potential population level effects. | <p>High</p> <p>Project C.1 Development of an agreed approach to assessing the potential effects of displacement from wave and tidal arrays</p> |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | An agreed approach to assessing the potential effects of displacement from tidal arrays | Determine whether or not displacement from demonstration scale / commercial scale tidal arrays is ever likely to result in biologically significant effects | High Project C.1 Development of an agreed approach to assessing the potential effects and consequences of displacement from wave and tidal arrays |
| Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | An agreed approach to assessing the potential effects of displacement from tidal arrays | If necessary, develop a consistent approach to assessing/modelling the risk to populations from displacement tidal projects. To enable Regulators to assess the risk. | Medium |
| Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | An agreed approach to assessing the potential effects of displacement from tidal arrays | If necessary, an agreed approach on how to measure/detect displacement is required. Can displacement be measured? What is a representative sample? How can potential significance of displacement be assessed? | Medium |
| Displacement | 4.1 Potential displacement of essential activities of marine mammals, basking sharks and birds | Potential for displacement to occur – research around demonstration scale arrays may provide an opportunity to gather data to inform commercial scale EIA/HRA. | If determined necessary, undertake research around first demonstration arrays to investigate if displacement occurs and to build an evidence base to inform our understanding of the behavioural response of animals to operational devices which may be used to inform commercial scale EIA/HRA. | Low |
| General | 5.1 Further strategic baseline data (distribution, abundance, seasonality, etc.) for marine mammals and basking sharks is required to better understand use of potential development areas | Understanding the functional use of sites by key species | Develop method/refinement of approach regarding how functional use/behavioural data could be used in assessments as an alternative to current approach which uses density data | Medium |
| General | 5.2 Further strategic baseline data (distribution, abundance, seasonality, etc.) for birds is required to better understand use of potential development areas | Understanding the functional use of sites by key species | Develop method/refinement of approach regarding how functional use/behavioural data could be used in assessments as an alternative to current approach which uses density data | Medium |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| General | 5.3 Further strategic baseline data (distribution, abundance, seasonality, etc.) for migratory fish is required to better understand use of potential development areas | Lack of distribution data for migratory fish | Method to measure distribution of migratory fish at sea | Medium |
| General | 5.4 An agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA is required | | | High Project E.6 Establish appropriate and proportionate objectives and methodologies for site characterisation surveys to inform EIA/HRA HOLD |
| General | 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA/HRA | Further data i.e. demographic parameters (e.g. adult survival, juvenile survival, productivity rates, etc.) for mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling. Current information on other sources of mortality and disturbance acting on marine mammal populations, such as fisheries by catch, is sparse. | Establish up-to date demographic parameters for key species to enable validation of models and to inform inputs to models. Lack of up to date data is a serious hindrance to research across the sector. | Medium |
| General | 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA/HRA | Agreement on the reference populations (and current status and trends) against which changes are assessed. NOTE: Interagency Marine Mammal Working Group has agreed management units for the five species that are considered to be of greatest concern: grey seal, harbour seal, harbour porpoise, bottlenose dolphin, and minke whale for reporting Favourable Conservation Status (FCS) however there is some debate about their appropriateness for use in project assessment. | Establish consistent rationales for defining populations using the best available information. | Medium |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| General | 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA/HRA | Agreement on the reference populations (and current status and trends) against which changes are assessed. NOTE: Interagency Marine Mammal Working Group has agreed management units for the five species that are considered to be of greatest concern: grey seal, harbour seal, harbour porpoise, bottlenose dolphin, and minke whale for reporting Favourable Conservation Status (FCS) however there is some debate about their appropriateness for use in project assessment. | The definition of management units will be an adaptive process: when more evidence becomes available these units can be updated for following applications. | Low |
| General | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | Improved understanding of population level impacts. | Review of existing modelling tools and of need for development of new tools to predict population level consequences of impacts on survival and reproductive success of individuals and hence population size. | High Project E.4 Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal energy projects |
| General | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | Improved understanding of population level impacts. | Population modelling of the scaling up of impacts | High Project E.4 Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal energy projects |
| General | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | Establishing the limits of acceptable impact under the terms of the Habitats Regulations for both European Protected Species and qualifying species of SACs and SPAs. | The PCoD project and ORJIP offshore wind PCAD project should help to provide frameworks for determining thresholds for impacts in terms of disturbance or mortality levels, but there is likely to be a need for some additional work to ascertain thresholds that fully meet the requirements of the Habitats Regulations and which are relevant to wave and tidal projects. | High Project E.4 Further research to improve understanding of the potential population level effects of protected mobile species from commercial scale wave and tidal energy projects |
| General | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts | Establishing the limits of acceptable impact under the terms of the Habitats Regulations for both European Protected Species and qualifying species of SACs and SPAs. | Develop a modelling and management framework appropriate for assessing the risks. Link results to the management of potential impacts on Favourable Conservation Status of protected sites/species. | High Project E.4 Further research to improve understanding of the potential population level effects of protected mobile |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | would improve confidence in EIA/HRA | | | species from commercial scale wave and tidal energy projects |
| Impacts on commercial fisheries | 6.1 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 | | | Low |
| Impacts on shipping and navigation | 7.1 Difficulties with assessing and mitigating the potential cumulative impacts on shipping and navigation due to uncertainty around risks that may arise from a number of projects | TBC | Extension and replication of SANAP for key strategic development areas | High Project G.1 Development of agreed methods/processes for assessing, mitigating and managing potential impacts on shipping and navigation |
| Impacts on seascape | 8.1 Lack of regional and local coastal landscape character assessments and objective assessment criteria to inform Seascape, Landscape and Visual Impact Assessment | Baseline coastal landscape character assessments at a national level outside of Scotland and Wales. | Character-based coastal landscape assessment at national level. | Low |
| Impacts on seascape | 8.1 Lack of regional and local coastal landscape character assessments and objective assessment criteria to inform Seascape, Landscape and Visual Impact Assessment | Baseline coastal landscape character assessments at a regional character level. | For areas where clusters for development are planned then a regional scale character based assessment should also be undertaken (or at a finer level than regional may be required on some complex areas of coast). | Medium |
| Impacts on seascape | 8.1 Lack of regional and local coastal landscape character assessments and objective assessment criteria to | Baseline coastal landscape character assessments at a local character level. | Detailed assessment at a local scale is appropriate to impact assessment of specific coastal or marine based developments. | Low |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | inform Seascape, Landscape and Visual Impact Assessment | | | |
| Impacts on seascape | 8.2 Lack of understanding regarding the economic value of seascape and any change in this as a result of renewable activities | | | Low |
| Social and economic impacts on local communities | 9.1 Difficulty with identifying, assessing, mitigating and managing potential cumulative social and economic impacts from marine energy development and changes to existing maritime activity | It is unclear what level and type of employment will be required to support wave and tidal projects. This makes assessing key socio-economic impacts difficult. | <p>Data collection in order to better understand the potential socio-economic impacts on local communities. Developers and supply chain should be engaged to provide predictions of the number and type of workers that will be required to support planned developments. This should include indicative timescales, consider project phasing etc.</p> <p>Although some work has already been done in this area by TCE this is several years old and now that some first demonstration projects have gained consent, those developers will be looking towards the construction phase and will have a better understanding of the level and type of employment that may be created.</p> | High Project D.1 Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |
| Social and economic impacts on local communities | 9.1 Difficulty with identifying, assessing, mitigating and managing potential cumulative social and economic impacts from marine energy development and changes to existing maritime activity | The potential cumulative economic impacts on local communities resulting from increased employment opportunities, supply chain development, or changes to existing industries from multiple demonstration projects within a region. | The methodology and baseline produced by ABPmer could be used to undertake a cumulative socio economic impact assessment at a regional basis if determined necessary/beneficial by the local authority/regulator(s)/advisors. | High Project D.1 Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |
| Social and economic impacts on local communities | 9.1 Difficulty with identifying, assessing, mitigating and managing potential cumulative social and economic impacts from marine energy development and changes to existing | The potential cumulative social impacts on local communities resulting from development of the wave and tidal industry (such as the effects on local services from any change in population during construction and operation) | <p>Socio-economic assessment as part of the EIA process is not a new topic but it is recognised that wave and tidal project will often happen in small rural communities, thus there is a potential for impacts to be magnified.</p> <p>A review of work underway in offshore wind ORJIP could be adapted / aligned with the needs of the wave and tidal industry.</p> | High Project D.1 Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | maritime activity | | | |
| Social and economic impacts on local communities | 9.1 Difficulty with identifying, assessing, mitigating and managing potential cumulative social and economic impacts from marine energy development and changes to existing maritime activity | The potential cumulative social impacts on local communities resulting from development of the wave and tidal industry (such as the effects on local services from any change in population during construction and operation) | A cumulative social impact assessment similar to ABPmer's ongoing socio-economic case studies, but where the emphasis is on the potential social impacts and benefits from development of a wave and/or tidal industry, with particular emphasis on the impacts on small rural communities. | High Project D.1 Further studies and research to understand the potential social and economic opportunities and impacts from the development of marine energy projects in rural communities |
| Impacts on physical processes | 10.1 Development of hydrographic models to predict the effects of changes in water flow and energy removal caused by (a) the physical presence of the device in the water (b) the removal of energy and secondary effects of changes in water flow and energy removal | | | Low |
| Impacts on physical processes | 10.2 Validation of hydrographic models to help predict the effects of changes in water flow and energy removal at commercial scale | | | Low |
| Regulatory | 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA | Improved understanding of population level impacts. | Establish an appropriate methodology e.g. such as using a modified version of PVA/PBR. Review of PBR approach to regulation including a consideration of alternatives. Briefing paper for Regulators and developers. | High Project F.1 Review of PBR approach to regulation including consideration of alternatives |
| Regulatory | 11.1 Method/processes are required to help manage perceived and identified environmental risks that may arise | Agreed methods and processes | Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process | High Project F.2 Development of methods/processes for identifying and managing |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | from wave and tidal developments to ensure that project level requirements are proportionate | | | environmental risks associated with wave and tidal energy developments within the consenting process |
| Regulatory | 11.2 Methods/processes are required to predict and measure potential cumulative impacts around clusters of lease areas | Work which goes beyond generic guidelines to demonstrate how cumulative impacts can be quantified and assessed. Requires standard approaches, agreed by Regulators that can be applied consistently by developers. | Development and agreement of methods/processes for predicting and measuring cumulative impacts around clusters of lease areas | Medium |
| Regulatory | 5.5 Further data of mobile species populations (particularly qualifying species of Natura sites and EPS) for use in population modelling would improve confidence in EIA/HRA | Approaches to determining connectivity of mobile qualifying features. | <p>Connectivity (protected sites and species): Understanding linkages between birds at sea and SPAs. Plug gaps in seabird tracking studies; improve our understanding of foraging areas associated with different breeding colonies.</p> <p>e.g. Methods for determining and quantifying which birds in a development area are from SPAs and if so, which sites. Key gap is understanding of connectivity to SPAs outwith the breeding season.</p> <p>e.g. Understanding linkages between migratory salmon (Natura species) and SACs. How to apportion populations to rivers and SAC sites.</p> | <p>High</p> <p>Project F.6 Methods are required for determining connectivity of mobile qualifying species from protected sites with development areas</p> <p>HOLD (SNH - Scotland, birds only)</p> |
| Regulatory | 11.3 Agreement is required on the approach to applying a design envelope approach to consenting wave and tidal arrays | TBC | TBC | <p>High</p> <p>Project F.3 Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays.</p> |
| Regulatory | 11.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans, incorporating adaptive management strategies, | TBC | TBC | <p>High</p> <p>Project F.4 Development and agreement of methods/processes for developing Project</p> |

| Topic | Key Issue | Gaps identified | Research area | Priority |
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| | for commercial scale wave and tidal arrays | | | Environmental Management Plans, incorporating mitigation measures and adaptive management strategies, for demonstration and commercial scale wave and tidal arrays. |
| Regulatory | 11.5 There is uncertainty as to how proposed SACs for harbour porpoise will be considered with regards to consented sites and future applications | TBC | TBC | High Project F.5 An agreed approach to undertaking any HRA with regards to proposed SACs for harbour porpoise is required. |