Ocean Energy

working to accelerate offshore consenting

ORJIP Ocean Energy

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

Report to: The Crown Estate, Marine Scotland, Welsh Government, Scottish Natural Heritage and Natural Resources Wales

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1 INTRODUCTION

1.1 BACKGROUND

The Offshore Renewables Joint industry Programme Ocean Energy (ORJIP Ocean Energy) was first funded in 2015 by The Crown Estate (TCE), Marine Scotland and Welsh Government (the Sponsors) as the result of 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 current projects in the UK. ORJIP Ocean Energy was designed to bring together industry, funders and researchers so that the sectors' Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA) consenting risks could be addressed in a timely manner and on a strategic basis. The Secretariat role was funded for an initial pilot phase, lasting approximately 15 months to June 2016. With the addition of funders Scottish Natural Heritage (SNH) and Natural Resources Wales (NRW), the first official phase of the project was run from June 2016 to June 2017. The Secretariat function is run by Aquatera and delivery partners MarineSpace and the European Marine Energy Centre (EMEC).

The first key task of the Secretariat during the pilot phase was to produce a published report outlining the strategic research priorities that would form the focus of ORJIP Ocean Energy. The first version of this report, entitled the Forward Look, was published in July 2015. The second version of the Forward Look was published in February 2016. The third iteration of the Forward Look is presented here. This version of the Forward Look has also been updated to include the priority consenting EIA/HRA issues for tidal lagoon developments following the ORJIP Ocean Energy workshop[1] held on 3 May, 2017 in Bristol during which stakeholders were consulted to identify and consolidate issues and priority research areas for the tidal lagoon sector.

The ORJIP OE Programme Brief gives a full description of the ORJIP OE Project including aims and objectives. It is available (along with the Forward Look) on the ORJIP Ocean Energy website at the link below:
http://www.orjip.org.uk/documents

1.2 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 funding programmes/strategies; and
- 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 current 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:

[1] Presentations from this workshop are available at: http://www.orjip.org.uk/tidal-range

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1.3 THE FORWARD LOOK

The Forward Look 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; key information and data gaps are addressed. To ensure that the Forward Look remains relevant and up-to-date, regular revisions are required.

This version of the Forward Look (Forward Look 3) presents the up-to-date priority issues for the wave and tidal current industries. This version of the Forward Look has also been updated to include the priority consenting EIA/HRA issues for tidal lagoon developments following the workshop held on 3 May, 2017 in Bristol. The key consenting issues and risks specific to tidal lagoon developments are presented separately in Chapter 5.

1.4 WAVE AND TIDAL CURRENT: OVERVIEW OF APPROACH

All databases were reviewed and updated to inform the development of this version of the Forward Look, including:

- Key consenting issues and risks;
- Research gap analysis; and
- Recommendations to address research gaps.

This review process was informed by a Call for Evidence issued to all Steering Group and Network members in May 2017. 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.

1.4.1 Production of a list of key consenting issues and risks

The list of consenting issues and risks presented in the previous version of the Forward Look was reviewed and updated following analysis of the responses to the Call for Evidence. 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 Forward Look were noted.

1.4.2 Development of research recommendations and identification of high priority projects

The research gap analysis undertaken during the previous Forward Look 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.

1.4.3 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;
- Indicative scale of cost for delivering the required research based on consultation with Network members; and
- Identification of candidate project Lead and Funders, based on consultation with Network members.

1.5 TIDAL LAGOONS – OVERVIEW OF APPROACH

The ORJIP Ocean Energy Tidal Range Workshop was held on 03 May 2017 in Bristol in partnership with NERC and Natural Resources Wales. During the workshop the consenting issues for tidal lagoon developments were identified and discussed. After the workshop these were then compiled into the;

- List of key consenting issues and risks; and,
- List of proposed priority research projects.

1.6 STRUCTURE OF THE FORWARD LOOK

The Forward Look is structured as follows:

- **Chapter 2:** Wave and tidal current: list of key consenting issues and risks
- **Chapter 3:** Wave and tidal current: research recommendations and list of priority projects
- **Chapter 4:** Wave and tidal current: outline project plans
- **Chapter 5:** Tidal lagoons: list of key consenting issues and risks and identification of proposed priority research projects
- **Chapter 6:** Conclusions and next steps
- **Chapter 7:** Appendices
    - **Appendix A:** High priority strategic research projects with considerable research underway/planned
    - **Appendix B:** Issues/risks no longer considered to be key strategic consenting issues – wave and tidal current
    - **Appendix C:** Wave and tidal current - Research gap analysis

2 WAVE AND TIDAL CURRENT: LIST OF KEY CONSENTING ISSUES AND RISKS

The list of consenting issues and risks for wave and tidal current presented in the previous version of the Forward Look was reviewed and updated following analysis of the responses to the Call for Evidence. 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 current projects, or both?** 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 sectors[2] 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 25 issues were identified as 'key strategic consenting issues' currently facing the wave and tidal current 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 A.

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

[2] These issues were identified as high priorities during the consultation process for the report Wave & Tidal Enabling Actions Report; Consolidation of wave and tidal EIA/HRA issues and research priorities, 2014. http://www.thecrownestate.co.uk/media/151984/consolidation-of-eia-hra-issues-and-research-priorities.pdf (Written by Aquatera, Published by The Crown Estate prior to the formation of ORJIP OE).

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

Topic	EIA/HRA issue	Relevant to wave or tidal current or both?	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 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	1.2 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	1.3 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.

Topic	EIA/HRA issue	Relevant to wave or tidal current or both?	Strategically relevant?	Commercial or demonstration scale?	Key issue in previous report?	Current 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.
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.

Topic	EIA/HRA issue	Relevant to wave or tidal current or both?	Strategically relevant?	Commercial or demonstration scale?	Key issue in previous report?	Current 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.
8. Social and economic impacts on local communities	8.1 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.

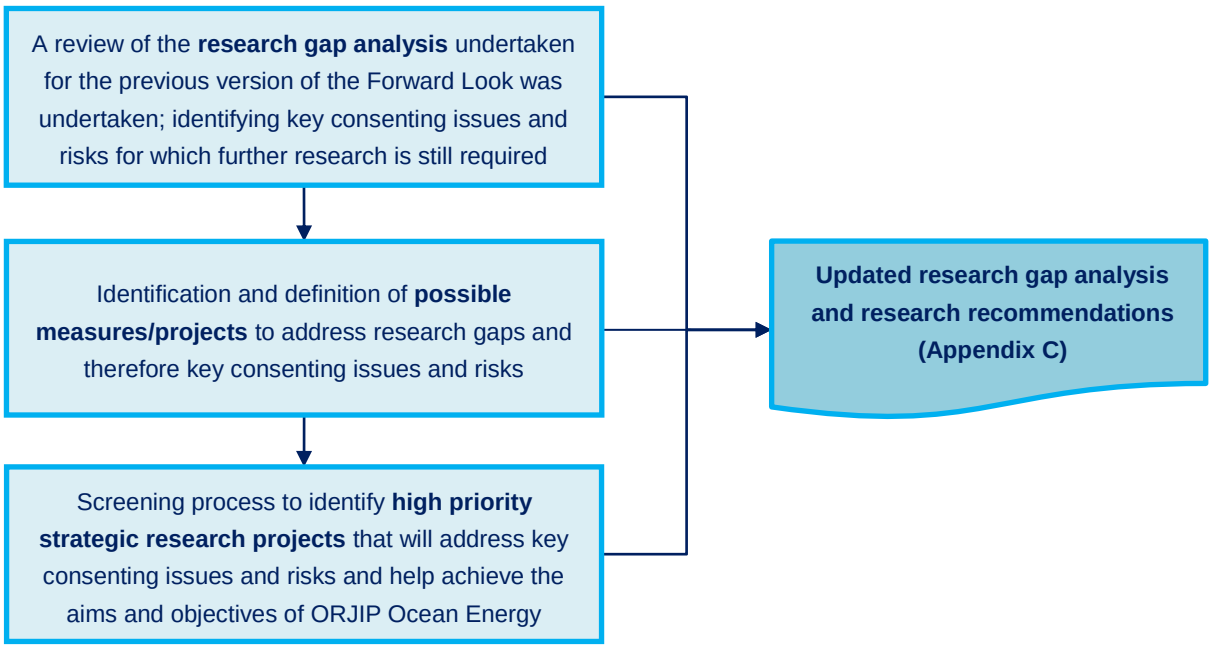
Topic	EIA/HRA issue	Relevant to wave or tidal current or both?	Strategically relevant?	Commercial or demonstration scale?	Key issue in previous report?	Current key strategic consenting issue?
Physical environment						
9. Impacts on physical processes	9.1 Development of hydrographic models to predict 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.
9. Impacts on physical processes	9.2 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						
10. Regulatory processes	10.1 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.
10. Regulatory processes	10.2 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.
10. Regulatory processes	10.3 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.

Topic	EIA/HRA issue	Relevant to wave or tidal current or both?	Strategically relevant?	Commercial or demonstration scale?	Key issue in previous report?	Current key strategic consenting issue?
10. Regulatory processes	10.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans and 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.
10. Regulatory processes	10.5 Further guidance is required as to how best to consider decommissioning in the consenting process.	Both	Yes, relevant to all projects	Demonstration and commercial	N/A	This remains a key strategic consenting issue.

3 WAVE AND TIDAL CURRENT - 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 Figure 3.1.

Figure 3.1 Identification of high priority strategic research projects



As shown above, the 'research gap analysis and research recommendations' from the previous Forward Look 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; and
- 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 were 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 considerable ongoing work or research planned in the near-term, are listed in Appendix A.

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

Please note that all medium and low priority projects identified during the screening process are listed in Appendix C. Should Network participants be planning to pursue any of these 'medium' or 'low' priorities for the wave and tidal current 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.

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
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)** • 1.1 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
	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)** • 1.1 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

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	A.3 Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays **Relevant key issue(s)** • 1.1 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
B. Underwater noise	B.1 Establishment of an acoustic 'evidence base' for operational devices and arrays **Relevant key issue(s)** • 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	✓	✓
	B.2 Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays **Relevant key issue(s)** • 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)** • 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)** • 8.1 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)** • 1.1 The nature of any interactions between marine mammals and basking sharks and tidal turbines is uncertain	✓	X

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	• 1.2 The nature of any interactions between diving birds and tidal turbines is uncertain • 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		
	E.2 Development of mitigation measures for identified and potential impacts of wave and tidal developments **Relevant key issue(s)** • 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	✓	✓
	E.3 Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays **Relevant key issue(s)** • 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
	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 **Relevant key issue(s)** • 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA	✓	✓
	E.5 Review and dissemination of findings of environmental monitoring studies **Relevant key issue(s)** • This is relevant to ALL key consenting issues	✓	✓
F. Regulatory issues	F.1 Review of Potential Biological Removal (PBR) approach to regulation including consideration of alternatives **Relevant key issue(s)** • 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA	✓	✓
	F.2 Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process	✓	✓

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	Relevant key issue(s) • 10.1 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		
	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)** • 10.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans, incorporating adaptive management strategies, for commercial scale wave and tidal arrays	✓	✓
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 considerable ongoing work or research planned in the near-term, are listed in Appendix A.

4 WAVE AND TIDAL CURRENT - 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.

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	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. 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 ever likely to be an issue for marine mammals; establishing the need for future baseline characterisation surveys and post-consent mitigation and monitoring.
Required outputs	• 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 and FORCE (Cape Sharp) and at early commercial projects such as MeyGen (Inner Sound), Nova Innovation (Bluemull Sound), and OpenHydro (Paimpol-Bréhat).
Relevant projects recently completed	• Lonergan, ML, Sparling, CE. & McConnell, BJ. (In review). Behavioural changes among harbour seals (*Phoca vitulina*) around an operational tidal turbine. Submitted to International Journal of Marine Science. • Williamson, B.; Fraser, S.; Blondel, P.; Bell, P.; Waggitt, J.; Scott, B. (2017). Multisensor Acoustic Tracking of Fish and Seabird Behaviour around Tidal Turbine Structures in Scotland. IEEE Journal of Oceanic Engineering, In Press (99), 1-18. • A review of collision risk monitoring undertaken to date is included in the OES Annex IV 2016 State of the Science Report Available at: https://tethys.pnnl.gov/sites/default/files/publications/Annex-IV-2016-State-of-the-Science-Report_LR.pdf • 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. • Monitoring undertaken around tidal turbines including those deployed at EMEC, ORPC (USA), OpenHydro (Canada), Verdant Power (USA).

Project A.1	Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment
Relevant projects currently planned or underway	• Monitoring planned at MeyGen - Scottish Government Demonstration Strategy – Phase 2 Monitoring around the first devices deployed at MeyGen and MeyGen KTP with University of Aberdeen. Lead contact Dr Beth E. Scott b.e.scott@abdn.ac.uk • 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 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. Preliminary results suggest overlap of pups and device is most likely to occur shortly after weaning. • SEACAMS2 Assessing the impact of the experimental DeltaStream tidal energy unit in Ramsey Sound (Pembrokeshire) on grey seals movements and energy expenditure. Seals will be tagged to monitor and reproduce 3D movements, behaviour and energy expenditure, using novel high-tech GPS-enabled 'Daily Diary' bio-logging devices developed by Swansea University. • Third-generation Adaptable Monitoring Package – Jan 2017 – Dec 2019. EWTEC paper submitted. Contact: Brian Polagye, University of Washington bpolagye@uw.edu
Candidate project(s)	• Deployment of FLOWBEC or EMEC's Integrated Monitoring POD at existing sites e.g. EMEC, MeyGen (FLOWBEC platform already being installed at MeyGen as part of Scottish Government's Demonstration Strategy (see above) however further deployments would be informative) (Possible funders - Scottish Enterprise/SDI/DECC SEA programme) • Deployments at test centres e.g. EMEC in 2017
Recommended actions	• 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	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. 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.
Required outputs	• Modelling hydrodynamics (size of animal, buoyancy, swim speed, etc) to investigate the probability of a marine mammal and a turbine blade occupying the same space at the same time, the likelihood of a collision occurring 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	• Monitoring undertaken around tidal turbines including those deployed at EMEC, ORPC (USA), OpenHydro (Canada), Verdant Power (USA), MeyGen (Inner Sound, Scotland)

Project A.2	Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals
recently completed	• MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Dr Beth Scott and Benjamin Williamson KTP Associate • PNNL harbour porpoise study re. consequence of collision with MCT (Wood, J.; Joy, R.; Sparling, C. (2016). Harbour Seal - Tidal Turbine Collision Risk Models. An Assessment of Sensitivities.) Report by SMRU Consulting. pp 57. • 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 (Lonergan, M. & Thompson, D. (2015) Collision risk and impact Study: Examination of models for estimating the risk of collisions between seals and tidal turbines. Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, no. MR 7.2.2, St Andrews, 15pp) • MS led project with SNH Contribution: Fine-scale harbour seal at-sea usage mapping around Orkney and the North coast of Scotland Scottish Marine and Freshwater Science Report Vol 7 No 27 Esther L. Jones, Sophie Smout, Clint Blight, Carol Sparling and Bernie McConnell http://live-marinedatascotland.getnucivic.com/sites/default/files/SMFS%200727_0.pdf • Marine Scotland/SNH - Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines (Band, Sparling, Thompson, Onoufriou, San Martin & West, 2016. Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines. Scottish Marine and Freshwater Science, Volume 7, Number 17. Available online: http://www.gov.scot/Resource/0050/00509891.pdf) • Study by SAMS assessing the usage of tidal streams by harbour porpoise. Riding the Tide: Use of a moving tidal stream habitat by harbour porpoises (Benjamins, S., 2016).
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• Update collision risk modelling fluid dynamics to be more reflective of actual hydrodynamics around turbine rotors. Could be led by any researcher group with strength in turbine simulation, experimental measurement, or field characterization. • CFD modelling to investigate the likelihood and consequences of collision events (Possible lead: Queens University Belfast/Edinburgh University)

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	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. 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.

Project A.3	Further development of instrumentation and methodologies for detecting potential collision events 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 ever likely to be an issue for marine mammals; establishing the need for future baseline characterisation surveys and post-consent mitigation and monitoring.
Required outputs	• 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
Relevant projects recently completed	• Williamson, B.; Fraser, S.; Blondel, P.; Bell, P.; Waggitt, J.; Scott, B. (2017). Multisensor Acoustic Tracking of Fish and Seabird Behavior around Tidal Turbine Structures in Scotland. IEEE Journal of Oceanic Engineering, In Press (99), 1-18. • 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. • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Dr Beth Scott and Benjamin Williamson KTP Associate • 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 may apply to ocean energy. • ORE Catapult Tidal Turbine Collision Detection - A review of the state-of-the-art sensors and imaging systems for detecting mammal collisions. Available at: https://ore.catapult.org.uk/wp-content/uploads/2016/05/Tidal-turbine-collision-sensor-development-sensors-review-report.pdf • Nekton Interaction Monitoring System (NIMS) (ended in 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. Available at: https://energy.gov/sites/prod/files/2017/03/f34/nekton-interactive-monitoring-system.pdf • Passive acoustic methods for fine-scale tracking of harbour porpoises in tidal rapids (MacAulay, J. D. J., Gordon, J. C. D., Gillespie, D. M., Malinka, C. E. & Northridge, S. P. Feb 2017 In : Journal of the Acoustical Society of America. 141, 2, p. 1120-1132) • SMRU/NERC/MREKE funded project to develop self-contained buoy tracking system (report due soon)
Relevant projects currently planned or underway	• Third-generation Adaptable Monitoring Package – January 2017 – December 2019. EWTEC paper submitted. Contact: Brian Polagye, University of Washington bpolagye@uw.edu • Ongoing: Marine Scotland/ SNH: Scottish Government Demonstration Strategy Phase 2 - Trialling methods for tracking the fine-scale underwater movements of marine mammals. This is the package of in-situ monitoring equipment being deployed around the MeyGen turbines in

Project A.3	Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays
	Inner Sound, via Scottish Government's demonstration strategy (and complementing MeyGen's own in-situ monitoring suite, delivered by Aberdeen University). Phase 1 report available: http://www.gov.scot/Resource/0050/00501574.pdf • SMRU Consulting has been awarded funding from the OESEA to analyse and publish harbour porpoise PAM data gathered by TEL within Ramsey Sound. • Deployment of EMEC Integrated Monitoring POD at EMEC's Fall of Warness tidal test site as part of InStream project.
Candidate project(s)	• Development of automated detection and acoustic deterrent systems for tidal devices. Possible lead: SMRU. This could possibly be undertaken in collaboration with work for ORJIP Offshore Wind or aquaculture funded work. • Further development of NIMS • "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) • Development of methods and systems suitable for monitoring marine mammal behaviour and collision risk around arrays • Development of analytical frameworks for the data that will be generated from monitoring equipment

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	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. This database needs to be maintained and hosted in such a way that maximises its future use in research and project development/consenting activities.
Required outputs	• Well maintained and accessible database to improve knowledge of underwater noise emitted by marine renewable devices and associated infrastructure
Location	• N/A
Relevant projects recently completed	• None identified
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• None identified
Recommended actions	• 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	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. 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. It will be important to consider how tidal flow and sea state might affect noise propagation and turbine noise modelling.
Required outputs	• 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	• N/A
Relevant projects recently completed	• 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 Available at: http://www.nerc.ac.uk/innovation/activities/infrastructure/offshore/emec-mreke-workshop/ • TCE and MS guidance on underwater noise • SAMS/Loughborough project to investigate the effects of flow speed on noise propagation – DECC funded
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• 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	• 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	• Review of models currently used to estimate displacement e.g. PcoD, PVA, CEH Displacement model. • Investigation into whether these models can be expanded to cover additional species considered sensitive to wave and tidal developments • Investigate if there is potential for wider application of the CEH Displacement Model for use in wave and tidal industries • Methods to assess displacement from large scale arrays and cumulative developments
Location	N/A
Relevant projects recently completed	• Joint SNCB Interim 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 (January 2017). Though focused on offshore windfarms, many of the principles will be equally applicable to wave and tide. Available at: http://jncc.defra.gov.uk/pdf/Joint_SNCB_Interim_Displacement_AdviceNote_2017.pdf • EMEC Wildlife Data Analysis Project (Long, C. 2017. Analysis of the possible displacement of bird and marine mammal species related to the installation and operation of marine energy conversion systems. Scottish Natural Heritage Commissioned Report No. 947.) • Marine Scotland – Sensitivity of metrics derived from Population Viability Analysis (PVA) Cook, A.S.C.P. & Robinson, R.A. 2016. Testing sensitivity of metrics of seabird population response to offshore wind farm effects. JNCC Report No. 553. JNCC, Peterborough. • Marine Scotland. A Protocol for Implementing the Interim Population Consequences of Disturbance (PCoD) approach: Quantifying and Assessing the Effects of UK Offshore Renewable Energy Developments on Marine Mammal Populations. Harwood, J., King, S., Schick, R., Donovan, C. & Booth, C. (2014) A Protocol for Implementing the Interim Population Consequences of Disturbance Model (PCOD) Approach: Quantifying and Assessing the Effects of UK Offshore Renewable Energy Developments on Marine Mammal Populations. Report No SMRUL-TCE-2013-014. Scottish Marine and Freshwater Science, 5(2).
Relevant projects currently planned or underway	• SMRU Consulting PCOD+ project (2016-2019). One of the five key tasks is to explore how marine mammal monitoring programmes can be tailored to assessing the population level effects of disturbance and critically, identify how early warning signals can be detected. This study will identify which potential type of data could be collected using existing and novel technologies and are most suitable for inclusion in a monitoring programme. See: http://www.smruconsulting.com/products-tools/pcod/pcod-plus-home/
Candidate project(s)	• Displacement assessment methods • Development of a displacement assessment framework suitable for wave and tidal developments • 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
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	• 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 production areas. • 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	• 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	Learn from communities already associated with marine energy e.g. Orkney, Islay, Strangford, Cornwall, Isle of Wight, Cromarty Firth, Caithness and Sutherland, Shetland, Western Isles, Rathlin, South Wales, Anglesey, etc. Engage with all levels of stakeholders
Relevant projects recently completed	• Research priorities for assessing potential impacts of emerging marine renewable energy technologies: Insights from developments in Wales (UK) (R.C. Roche, et al., Research priorities for assessing potential impacts of emerging marine renewable energy technologies: Insights from developments in Wales (UK), Renewable Energy (2016), Available at: https://www.researchgate.net/publication/306065970_Research_priorities_for_assessing_potential_impacts_of_emerging_marine_renewable_energy_technologies_Insights_from_developments_in_Wales_UK • MS Community benefits report –Local Energy Scotland – Scottish Government Good Practice Principles for Community Benefits from Offshore Renewable Energy Developments. Available at: http://www.localenergyscotland.org/media/77721/Good-Practice-Principles-for-Offshore-Community-Benefits.pdf • Human Dimensions of Tidal Energy. A case study comparison of attitudes towards current energy development in urban (Washington, US) and rural (Alaska, US) communities. Dreyer, S.; Polis,

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
	H.; Jenkins, L. (2017). Changing Tides: Acceptability, Support, and Perceptions of Tidal Energy in the United States. Energy Research & Social Science, 29, 72-83. • New Economics Foundation (2017) A socio-economics benefits assessment of the Celtic Seas Partnership. Available at: http://www.celticseaspartnership.eu/wp-content/uploads/2017/05/Socio-economic-benefits-assessment-of-the-Celtic-Seas-Partnership-co-existence-guidelines_NEFC_logo.pdf • Marine Energy Pembrokeshire (2015) Marine Energy in Wales Investment, Jobs, Supply Chain: – http://www.marineenergywales.co.uk/wp-content/uploads/2016/03/Marine-Energy-in-Wales-Investment-Jobs-Supply-Chain-2015-m.pdf • The Crown Estate (2012) A Socio-economic Methodology and Baseline for Pentland Firth and Orkney Waters Wave and Tidal Developments. Available at: https://www.thecrownestate.co.uk/media/152036/socio-economic-methodology-and-baseline-for-pfow-wave-tidal-developments.pdf • Marine Scotland and Sciencewise-ERC - Community engagement: assessing the social impacts of marine renewables. A two-way conversation with the people of Scotland on the Social Impact of offshore renewables. Presentation available at: http://www.snh.gov.uk/docs/A1891521.pdf • Development of guidance for undertaking economic impact assessment – Marine Scotland
Relevant projects currently planned or underway	• Oxford Brookes University – (June 2017 – October 2019) - The socio-economic impact of offshore wind on the human environment. The project will analyse the socio-economic effects of Vattenfall's EOWDC from the construction stage through to becoming fully operational to help better understand how offshore wind developments can be maximised to benefit the region and local communities. Although the focus of the work is on offshore wind, some of the principles might apply to ocean energy.
Candidate project(s)	• 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
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	• 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

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
Relevant projects recently completed	• Lonergan, ML, Sparling, CE. & McConnell, BJ. (In review). Behavioural changes among harbour seals (*Phoca vitulina*) around an operational tidal turbine. Submitted to International Journal of Marine Science. • Williamson, B.; Fraser, S.; Blondel, P.; Bell, P.; Waggitt, J.; Scott, B. (2017). Multisensor Acoustic Tracking of Fish and Seabird Behavior around Tidal Turbine Structures in Scotland. IEEE Journal of Oceanic Engineering, In Press (99), 1-18. • Waggitt, J.; Cazenave, P.; Torres, R.; Williamson, B.; Scott, B. (2016). Quantifying Pursuit-Diving Seabirds' Associations with Fine-Scale Physical Features in Tidal Stream Environments. Journal of Applied Ecology, 53(6), 1653-1666. • Monitoring undertaken around tidal turbines including those deployed at EMEC, ORPC (USA), OpenHydro (Canada), Verdant Power (USA). • Monitoring undertaken around wave devices to date including those deployed at EMEC. • 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.
Relevant projects currently planned or underway	• Monitoring planned at MeyGen - Scottish Government Demonstration Strategy – Phase 2 Monitoring around the first devices deployed at MeyGen and MeyGen KTP with University of Aberdeen. Lead contact Dr Beth E. Scott b.e.scott@abdn.ac.uk • Monitoring planned including at EMEC and FORCE (Cape Sharp) and at early commercial projects such as MeyGen (Inner Sound), Nova Innovation (Bluemull Sound), OpenHydro (Paimpol-Bréhat). • 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 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. Preliminary results suggest overlap of pups and device is most likely to occur shortly after weaning. • Third-generation Adaptable Monitoring Package – January 2017 – December 2019. EWTEC paper submitted. Brian Polagye, University of Washington bpolagye@uw.edu • VertIBase - Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy. NERC KE (2016-18) Aim: To synthesise, translate and embed the latest knowledge and understanding on marine vertebrate interactions with wave and tidal energy devices and developments to improve evidence-based decision-making, thus reducing risks to technology and site developers, investors, regulators and stakeholders. • SMRU Consulting has been awarded funding from the OESEA to analyse and publish harbour porpoise PAM data gathered by TEL within Ramsey Sound. • SEACAMS2 Assessing the impact of the experimental DeltaStream tidal energy unit in Ramsey Sound (Pembrokeshire) on grey seals movements and energy expenditure. Seals will be tagged to monitor and reproduce 3D movements, behaviour and energy expenditure, using novel high-tech GPS-enabled 'Daily Diary' bio-logging devices developed by Swansea University. • Ecology of black guillemots in relation to marine protected areas and marine renewable energy developments, October 2015-April 2019 (MASTS PhD).
Candidate project(s)	• Deployment of FLOWBEC or EMEC's Integrated Environmental Monitoring Platform at existing sites e.g. EMEC, MeyGen (FLOWBEC platform already being installed at MeyGen as part of Scottish Government Demonstration Strategy, see above) (Possible funders – Scottish Enterprise/SDI/DECC SEA programme) • Potential for new instrumentation and/or algorithms to be implemented by third parties during

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
	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 actions	• 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 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	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. 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.
Required outputs	• 'Toolbox' of existing mitigation measures for wave, tidal current 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	N/A
Relevant projects recently completed	• Annex IV and ORJIP Ocean Energy's workshop on Managing the Potential Environmental Effects of Wave and Tidal Projects held in Glasgow on 9th May 2017. The aim is to create a 'Toolbox' of existing environmental management and mitigation measures using the outputs of this workshop. In draft, available soon at: https://tethys.pnnl.gov/marine-energy • Marine Scotland - Evaluating and Assessing the Relative Effectiveness of Acoustic Deterrent Devices and other Non-Lethal Measures on Marine Mammals. Coram, A., Gordon, J., Thompson, D. and Northridge, S (2014). Evaluating and assessing the relative effectiveness of non-lethal measures, including Acoustic Deterrent Devices, on marine mammals. Scottish Government. • Methods to manage seal populations using ADDs at fish farms however method may also be useful for marine renewables. Non-lethal management of carnivore predation: long-term tests with a startle reflex-based deterrence system on a fish farm. Gotz, T. & Janik, V.M. (2016) Animal Conservation 19: 212–221. The Zoological Society of London • ORJIP Project 4, Phase 1 Use of Deterrent Devices and Improvements to Standard Mitigation during Piling (SMRU Marine and Xodus). Although the focus of the work has been on offshore wind, some of the principles may apply to ocean energy. Available at: https://www.carbontrust.com/media/416650/orjip-project-4-phase-1-summary-report.pdf
Relevant projects currently planned or underway	• NERC-funded VertIBase (April 2016 – March 2018) - Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy technologies. Lead Research Organisation: Cranfield University.

Project E.2	Development of mitigation measures for identified and potential impacts of wave and tidal developments
Candidate project(s)	• Trial of acoustic deterrent devices (ADDs) to determine their efficacy in tidal environments • Determine the relative effectiveness of ADDs on seals and cetaceans • Targeted activation of ADDs if animal is encountered in close proximity to a tidal turbine.

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	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. 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. 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	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 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.
Location	Test sites and first arrays
Relevant projects recently completed	• Williamson, B.; Fraser, S.; Blondel, P.; Bell, P.; Waggitt, J.; Scott, B. (2017). Multisensor Acoustic Tracking of Fish and Seabird Behavior around Tidal Turbine Structures in Scotland. IEEE Journal of Oceanic Engineering, In Press (99), 1-18. • 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. • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Dr Beth Scott and Benjamin Williamson KTP Associate

Project E.3	Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays
	• NIMS (through 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. • Passive acoustic methods for fine-scale tracking of harbour porpoises in tidal rapids (MacAulay, J. D. J., Gordon, J. C. D., Gillespie, D. M., Malinka, C. E. & Northridge, S. P. Feb 2017 In : Journal of the Acoustical Society of America. 141, 2, p. 1120-1132) • SMRU/NERC/MREKE funded project to develop self-contained buoy tracking system (report due soon).
Relevant projects currently planned or underway	• Marine Scotland/ SNH: Scottish Government Demonstration Strategy Phase 2 - Monitoring around the first devices deployed at MeyGen. Phase 1 now complete: Trialling methods for tracking the fine-scale underwater movements of marine mammals. This is the package of in-situ monitoring equipment deployed around the MeyGen turbines in Inner Sound. Phase 1 report available: http://www.gov.scot/Resource/0050/00501574.pdf • Third-generation Adaptable Monitoring Package – January 2017 – December 2019. EWTEC paper submitted. Brian Polagye, University of Washington bpolagye@uw.edu • 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 is working with PML and others to develop a Biofoul map of UK wave & tidal sites and looking at current Biofoul sensor technology. • SEACAMS2 Effective Environmental Data Collection - Trial aerial and underwater imagery using an unmanned aerial vehicle (UAV) and underwater videography in combination with land based visual tracking as well as acoustic methods.
Candidate project(s)	• Deployment of FLOWBEC or EMEC's Integrated Monitoring POD at existing sites e.g. EMEC, MeyGen (FLOWBEC platform already being installed at MeyGen as part of Scottish Government's Demonstration Strategy (see above) however further deployments would be informative (Possible funders – Scottish Enterprise/SDI/DECC SEA programme) • Deployments at test centres e.g. EMEC in 2017 • 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 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. Confidence in EIA/HRA would be improved by establishing methods appropriate for use for assessing population level risks to mobile species populations particularly to inform cumulative impact assessments.

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
	The development of methodologies and tools for use in assessing population level effects and where appropriate, determining if acceptable thresholds for mobile species populations across multiple projects or in combination with other impacts can be determined. 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.
Required outputs	• 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 • 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 recently completed	• Acceptable thresholds of change: how much is too much? A review of population assessment on marine mammals. SMRU Consulting report for NRW. Due to complete July 2017. Lead contacts Tom Stringell tom.stringell@naturalresourceswales.gov.uk and Kate Smith kate.smith@naturalresourceswales.gov.uk • EcoWATT 2050 EPSRC (2014-2017) Impacts of Very Large Scale Arrays and their Regulation. EcoWatt2050 seeks to provide the underpinning science for the strategic policy development and planning being undertaken by the regulatory authorities for marine renewable energy. The overarching objective is to determine ways in which marine spatial planning and policy can enable the maximum sustainable level of marine energy extraction, minimizing environmental impacts and ensuring that these meet the requirements of European law. It builds on an existing EPSRC project (TeraWatt), extending its outputs considerably to very large scale array deployments and mixes of technologies in order to determine the limits to energy extraction, and the criteria necessary to satisfy European and UK law. • Marine Scotland. A Protocol for Implementing the Interim Population Consequences of Disturbance (PCoD) approach: Quantifying and Assessing the Effects of UK Offshore Renewable Energy Developments on Marine Mammal Populations. Harwood, J., King, S., Schick, R., Donovan, C. & Booth, C. (2014) A Protocol for Implementing the Interim Population Consequences of Disturbance Model (PCOD) Approach: Quantifying and Assessing the Effects of UK Offshore Renewable Energy Developments on Marine Mammal Populations. Report No SMRUL-TCE-2013-014. Scottish Marine and Freshwater Science, 5(2). • A displacement model for foraging seabirds has been developed for offshore wind farms. A similar model could be developed for W&T projects – Marine Scotland, 2016. http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/ceh
Relevant projects currently planned or underway	• NERC CASE PhD studentship, based at the University of Aberdeen (2017-2020). INDI-POP Individuals to Populations: The potential effects of large tidal arrays on mobile marine populations. This research will be at the forefront of detailed individual-to-population modelling and add accurate functional response relationships between changes in energy/time use in individuals so as to be able to assess the relative risks of significant changes at population levels due to the addition of large scale renewable developments. • SMRU Consulting PCOD+ project (2016-2019). One of the five key tasks is to explore how marine mammal monitoring programmes can be tailored to assessing the population level effects of disturbance and critically, identify how early warning signals can be detected. This study will identify which potential type of data could be collected using existing and novel technologies and are most suitable for inclusion in a monitoring programme. See: http://www.smruconsulting.com/products-tools/pcod/pcod-plus-home/

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
	• "Sparling et al (2017)Guide to population models used in marine mammal impact assessment" http://jncc.defra.gov.uk/page-7446
Candidate project(s)	• Review of different models that are currently being used to assess population level effects e.g. PcoD, PBR, PVA. In particular, PVA is considered to have potential for assessments relating to marine mammals and marine renewable energy developments in part because it is widely used in seabird assessments.

Project E.5	Review and dissemination of findings of environmental monitoring studies
Aim	To provide regulators, industry and stakeholders with the best available information regarding the potential environmental impacts of wave and tidal developments
Objectives	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. 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.
Required outputs	• 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 learnt etc. • 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 recently completed	• SEACAMS database for sharing and disseminating findings from SEACAMS2 marine energy research programme http://www.imardis.org/ Lead contact: Dave Mills, Bangor University d.mills@bangor.ac.uk • OES Annex IV (including the Tethys database, webinars, expert forums and State of the Science Report led by the Pacific Northwest National Laboratory) • Marine Energy Wales Welsh Offshore Energy Research Database (WOERD). See http://www.marineenergywales.co.uk/developers/research/mep-research-evaluation/
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• Continuation and expansion of OES Annex IV

Project E.5	Review and dissemination of findings of environmental monitoring studies
Recommended actions	• 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 Potential Biological Removal (PBR) approach to regulation including consideration of alternatives
Aim	To review the existing PBR based approach to consenting marine energy projects in the UK and to identify and consider alternatives
Objectives	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. 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.
Required outputs	• 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 recently completed	• Acceptable thresholds of change: how much is too much? A review of population assessment on marine mammals. SMRU Consulting report for NRW. Due to complete July 2017. Lead contacts Tom Stringell tom.stringell@naturalresourceswales.gov.uk and Kate Smith kate.smith@naturalresourceswales.gov.uk • Marine Scotland Fine-scale harbour seal at-sea usage mapping around Orkney and the North coast of Scotland (Scottish Marine and Freshwater Science Report Vol 7 No 27 Esther L. Jones, Sophie Smout, Clint Blight, Carol Sparling and Bernie McConnell http://live-marinedatascotland.getnucivic.com/sites/default/files/SMFS%200727_0.pdf) • Scientific advice on matters related to the management of seal populations – briefing paper to Special Committee on Seals (SMRU, 2016) http://www.smru.st-andrews.ac.uk/files/2017/04/SCOS-2016.pdf • Critical knowledge gaps: estimating potential maximum cumulative anthropogenic mortality limits of key marine mammal species to inform management (Mackay, A., 2016). http://www.frdc.com.au/research/Final_reports/2015-035-DLD.pdf. This research was carried out in Australia, but lessons learnt may be relevant in a UK and European context.
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• Review the existing PBR based approach (particularly in relation to harbour (common) seals (*Phoca vitulina*) to consenting marine energy projects in the UK and to identify and consider

Project F.1	Review of Potential Biological Removal (PBR) approach to regulation including consideration of alternatives
	alternatives • Comparison of existing population tools, and investigation of potential suitability of use of PVA for seal populations in assessments relating to marine renewable energy developments (currently PVA is widely used in seabird assessments) • Levels of acceptable effect/take; what is considered acceptable for common (harbour) seal populations?
Recommended actions	• Feedback results from workshop on 'methods for assessing impacts on seal populations' on 3rd Feb 2016

Project F.2	Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process
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	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. 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.
Required outputs	• 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
Relevant projects recently completed	• NRW advice to Welsh Government on marine plan opportunities to guide the sustainable use of Welsh sea: tidal stream energy case study. Report due to be shared in Q3 2017, details possible mechanisms for delivering a more proportionate, risk-based approach to consenting. Lead contact Kate Smith NRW kate.smith@naturalresourceswales.gov.uk • NRW Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales (July 2015) https://naturalresources.wales/evidence-and-data/research-and-reports/guidance-to-inform-marine-mammal-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. • 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

Project F.2	Development of methods/processes for identifying and managing environmental risks associated with wave and tidal energy developments within the consenting process
Relevant projects currently planned or underway	• NERC-funded VertIBase (April 2016 – March 2018) - Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy technologies. Lead Research Organisation: Cranfield University.
Candidate project(s)	• 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	• 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.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
Aim	To provide methods and procedures for developing PEMPs for commercial scale, long term 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 PEMPs and adaptive management strategies to enable the development of commercial scale and long term PEMPs for wave and tidal projects.
Required outputs	• Review of PEMP (or similar) development and reporting processes from other marine industries • Review of single device and demonstration array PEMPs developed to date • Guidance/suite of tools for developing, consulting on and implementing project specific PEMPs including; stakeholder engagement plans, reporting timescales and requirements, feedback mechanisms, etc.
Location	N/A
Relevant projects recently completed	• All marine licences which have required a PEMP as a consent condition (see marine licence info available at: http://www.orjip.org.uk/Wave-Tidal-Project-Info) • Adaptive Management Plans for MCT (Strangford Lough), Anglesey Skerries and Swansea Bay Tidal Lagoon • EMEC Environmental Appraisal – guidance on PEMP development • FORCE Adaptive Management Plan • OpenHydro Snohomish PUD Adaptive Management Plan • Development Zone workshops https://www.thecrownestate.co.uk/media/501992/ei-uk-wave-and-tidal-demonstration-zones-workshop.pdf • NSIPs process – development of Evidence Plans • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Dr Beth Scott and Benjamin Williamson KTP Associate • Assessing Environmental Effects (WREN) Adaptive Management White Paper (Hanna, L., 2016) • Towards an integrated approach to marine benthic monitoring (Frojan, C., 2016). • TEL DeltaStream CMAMP and supporting work. • Minesto Deep Green

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
Relevant projects currently planned or underway	• EMEC Monitoring Advisory Group are looking at monitoring requirements
Candidate project(s)	• Development of guidance for producing Project Environmental Management Plans

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	• SANAP for key strategic development areas • Site suitability mapping tool that considers navigational safety
Location	N/A
Relevant projects recently completed	• Strategic Area Navigation Appraisal (SANAP) for the Pentland Firth and Orkney Waters Strategic Area (Anatec) • NOREL guidance on under keel clearance
Relevant projects currently planned or underway	• None identified
Candidate project(s)	• Strategic Area Navigation Appraisal (SANAP) for key development areas • Development of a navigational site suitability screening tool

5 TIDAL LAGOONS

5.1 TIDAL LAGOONS - LIST OF KEY CONSENTING ISSUES AND RISKS

The ORJIP Ocean Energy Tidal Lagoon Workshop was held on 03 May 2017 in Bristol in partnership with NERC and Natural Resources Wales (NRW). During the workshop consenting issues, evidence gaps and risks for tidal lagoon developments were identified and discussed. Following the workshop a list of key consenting issues and proposed priority research projects was compiled by the ORJIP OE secretariat, informed by the workshop discussions. The list of all the key consenting issues, evidence gaps and risks for tidal lagoon developments identified during the workshop is shown in Table 5.1. Not all the EIA/HRA issues detailed below are important at a strategic level, i.e. some will be very project and site-specific. Therefore, the final column of the table identifies issues that are more important at a strategic level.

Table 5.1 List of key consenting issues – tidal lagoons

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
THEME 1: Physical Processes			
1. Physical Processes (EIA Characterisation Data)	1.1 Understanding the need for, level, scope and quality of physical baseline data and characterisation deemed appropriate to inform EIA/HRA/WFD assessment requirements and predictive models (including sediment budgets and pathways).	Yes, relevant to all tidal lagoon projects	No
1. Physical Processes (Impact Assessment)	1.2 The need to (a) collate and evaluate the efficacy of available modelling tools and other assessment techniques to predict near and far-field and medium to long-term morphological changes arising from single or multiple tidal range developments and (b) innovate and develop existing models as well as improve capabilities with regards to application of such modelling tools.	Yes, relevant to all tidal lagoon projects	**Yes**
1. Physical Processes (Impact Assessment)	1.3 Understanding and predicting changes to physical processes (hydrodynamics including tidal and wave characteristics, sediment dynamics, geomorphology) in an estuary/system, as a result of schemes, both near and far field (plus associated indirect loss and changes to habitats and species). Need to agree procedures to define study boundaries and appropriate grid resolution for single or multiple tidal range developments.	Yes, relevant to all tidal lagoon projects	**Yes**
1. Physical Processes (Impact Assessment)	1.4 Understanding and predicting impact of single and multiple lagoon projects on water quality (turbidity and pathogens) – WFD and fisheries implications.	Yes, relevant to all tidal lagoon projects	**Yes**
1. Physical Processes (Impact Assessment)	1.5 Agreed procedures are needed for assessing and modelling effects of decommissioning scenarios of single or multiple tidal range developments on the future baseline environment (evaluation of existing methods and models).	Yes, relevant to all tidal lagoon projects	**Yes**

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
1. Physical Processes (Impact Assessment)	1.6 Agreed approach or suitable model for cumulative impact assessment of structures on physical processes.	Yes, relevant to all tidal lagoon projects	**Yes**
1. Physical Processes (Impact Assessment)	1.7 Validation of computational models to predict wakes from turbines within lagoon structures.	Yes, relevant to all tidal lagoon projects	No
1. Physical Processes (Flood Risk)	1.8 Understanding the potential for changes to existing areas of flood risk (as a result of tidal range developments) and how a project might affect the integrity and standard of coastal defences.	Yes, relevant to all tidal lagoon projects	No
1. Physical Processes (Sea Level Rise)	1.9 Need to ensure that discussion undertaken and consensus reached between industry and regulators on the key assumptions that should be used to inform existing models used to better understand the compounding effect of projected Sea Level Rise (SLR) on other pressures and impacts. In particular changing tidal levels, shifting habitats (in response to extreme events) in-combination with the impacts of project-level developments themselves.	Yes, relevant to all tidal lagoon projects	**Yes**
THEME 2: Biological Receptors			
2. Benthic Ecology (Impact Assessment)	2.1 Understanding the likely impacts of tidal range developments on planktonic communities within impoundments and corresponding uncertainty with respect to how to calculate impacts to algal communities and/or on primary production.	Yes, relevant to all tidal lagoon projects	No
2. Benthic Ecology (Impact Assessment)	2.2 Understanding how tidal range developments (including associated artificial hard substrates and shipping associated with the sourcing of aggregate materials for construction) might affect the introduction, rate and spread of Marine Invasive Non-Native species (MINNS)	Yes, relevant to all tidal lagoon projects	No
2. Benthic Ecology (Coastal Ecology)	2.3 Understanding the potential effects of impoundment on saltmarsh habitat (not possible to fully investigate until actual lagoon built).	Yes, relevant to all tidal lagoon projects	No
3. Fish (EIA Characterisation Data)	3.1 Need for increased understanding for all stages of the life cycle of key diadromous and marine fish species (each species would have the opportunity to interact with a tidal lagoon at least twice, as a juvenile and an adult).	Yes, relevant to all tidal lagoon projects	**Yes**

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
3. Fish (EIA Characterisation Data)	3.2 Need for increased understanding and data on the migratory routes of diadromous fish (particularly eel, lamprey, shad and salmon) and on habitat utilisation of these species within or adjacent to proposed lagoon developments. Need to develop methods to gather such information. These data needed to inform fish modelling work and to verify parameters used in Individual Based Modelling (IBM)).	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (EIA Characterisation Data)	3.3 Review and recommendations for appropriate and proportionate objectives and methodologies for fish characterisation surveys to inform EIA / HRA /WFD (study should also list all existing programmes and data (e.g. Instituut voor Natuur- en Bosonderzoek – INBO) and investigate scope for data sharing networks to be established.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (EIA Characterisation Data)	3.4 Development of agreed methodology to identify and quantify fish population modelling parameters and key data requirements for species of concern (links with 3.1, 3.2 and 3.3.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (EIA Characterisation Data)	3.5 Development of existing or new tools and approaches for stock assessment and population level impact assessment for key marine and diadromous fish species. Impact thresholds must be realistic, i.e. can actually be detected via available monitoring techniques.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (EIA Characterisation Data)	3.6 Development of tools / agreed approaches for assessing the economic value of river/estuarine/coastal fisheries (commercial/recreational/heritage).	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (EIA Characterisation Data)	3.7 Development of fish tagging/tracking technology (and correct methods of obtaining and handling sufficient numbers of fish) to provide suitable data to inform modelling and EIA work needed for lagoon projects. To include technology suitable for use on juvenile fish.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (Water Quality Impacts)	3.8 Understanding the potential synergistic and/or cumulative effects of (construction) contaminants on fish and prey species.	Yes, relevant to all tidal lagoon projects	No
3. Fish (Underwater noise)	3.9 Understanding the effects of construction / operational turbine noise on hearing ranges for key fish species (and risk of barrier effect) and whether this results in avoidance.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (Collision Risk)	3.10 Development of a lagoon-specific fish collision modelling approach that is accepted across industry and regulators.	Yes, relevant to all tidal lagoon projects	**Yes**
3. Fish (Entrainment)	3.11 Understanding the risk of (i) multiple turbine passes and risk of re-entrainment and (ii) sub-lethal damage and development of appropriate or novel modelling and assessment tools.	Yes, relevant to all tidal lagoon projects	**Yes**

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
3. Fish (Impact Assessment)	3.12 Need to increase understanding of the responses of fish to changes in migratory cues as a result of tidal range developments.	Yes, relevant to all tidal lagoon projects	No
3. Fish (Impact Assessment)	3.13 Need to increase understanding of the impact of physical barriers and constrained tidal flow on diadromous fish species utilising estuaries within impounded area, i.e. is migration upstream and downstream hindered by change in tidal flows/delays in passage.	Yes, relevant to all tidal lagoon projects	**Yes**
4. Marine Mammals (EIA Characterisation)	4.1 Understanding the temporal and geographical distribution of marine mammals at proposed sites and wider region.	Yes, relevant to all tidal lagoon projects	No
4. Marine Mammals (Impact Assessment/Loss of Habitat)	4.2 Understanding impacts on near and far field hydrodynamics and corresponding consequences for marine mammal feeding and foraging areas via development / innovation to deliver marine mammal encounter models specific to renewable technology such as Tidal Lagoons.	Yes, relevant to all tidal lagoon projects	**Yes**
4. Marine Mammals (Impact Assessment)	4.3 Need to establish and agree the most appropriate approach for determining the limit/threshold of acceptable mortality for a number of marine mammal species	Yes, relevant to all tidal lagoon projects	**Yes**
4. Marine Mammals (Underwater Noise)	4.4 Understanding the possible effects of underwater noise from the construction and operation of tidal range developments on marine mammals and e.g. impacts such as injury, disturbance, masking of vocalisations.	Yes, relevant to all tidal lagoon projects	**Yes**
4. Marine Mammals (Impact Assessment / Entrapment)	4.5 Understanding potential risks and consequences of entrapment for marine mammals	Yes, relevant to all tidal lagoon projects	No
5. Ornithology (EIA Characterisation)	5.1 Appropriate and proportionate objectives and methodologies which apply/ integrate use of novel technologies for site characterisation surveys to inform EIA / HRA is required.	Yes, relevant to all tidal lagoon projects	**Yes**
5. Ornithology (Impact Assessment)	5.2 Understanding impacts of intertidal and subtidal habitat distribution and composition and consequences for food availability and foraging behaviour of birds (and consequent impacts on relevant bird populations) via development of reliable IBM and Habitat Association Modelling tools.	Yes, relevant to all tidal lagoon projects	**Yes**
5. Ornithology (Impact Assessment)	5.3 Need to establish and agree the most appropriate approach for determining the limit/threshold of acceptable mortality for a number of bird species.	Yes, relevant to all tidal lagoon projects	**Yes**

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
THEME 3: Mitigation and Compensation			
6. Nature Conservation (Mitigation/Compensation)	6.1 Development of innovative approaches and models for improving capability to predict environmental responses to compensatory measures over varying timescales.	Yes, relevant to all tidal lagoon projects	No
6. Nature Conservation (Mitigation/Compensation)	6.2 Understanding / addressing conflicts between need for compensation habitat creation and other statutory obligations (e.g. designated sites). Offset should not contradict or compete directly with other offset requirements (e.g. shoreline management plan compensation).	Yes, relevant to all tidal lagoon projects	No
6. Nature Conservation (Mitigation/Compensation)	6.3 Develop agreed set of options and principles for creation of compensation habitat, particularly for features that cannot easily be created.	Yes, relevant to all tidal lagoon projects	**Yes**
6. Nature Conservation (Mitigation/Compensation)	6.4 Agree standard set of "success criteria" for compensation habitat measures.	Yes, relevant to all tidal lagoon projects	No
6. Nature Conservation (Physical Processes Mitigation and Monitoring)	6.5 Development of novel / emerging technologies tools and methods for monitoring long-term changes in mudflat levels /morphological changes, i.e. X-Band Radar, Satellite imagery, drone imagery, and demonstration needs for routine applications.	Yes, relevant to all tidal lagoon projects	**Yes**
6. Nature Conservation (Benthic Ecology Mitigation)	6.6 Understanding the feasibility, likely effectiveness of habitat translocation / re-creation and development of innovative approaches as mitigation/compensation measures.	Yes, relevant to all tidal lagoon projects	**Yes**
6. Nature Conservation (Benthic Ecology Mitigation)	6.7 Understand / demonstrate the potential for integrated aquaculture ecosystems inside tidal impoundments to promote restoration of local marine species, generate and maintain high levels of biodiversity and provide multiple ecosystem services.	Yes, relevant to all tidal lagoon projects	No
6. Nature Conservation (Fish Ecology Mitigation)	6.8 Need to increase understanding of options for mitigation and monitoring strategies for marine/estuarine and freshwater diadromous fish (including noise/light deterrents)	Yes, relevant to all tidal lagoon projects	**Yes**
6. Nature Conservation (Marine Mammal Mitigation)	6.9 Understanding mitigation options for impacts to marine mammals, including the use of different types of pingers.	Yes, relevant to all tidal lagoon projects	No

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
Theme 4: Human Environment			
7. Other users	7.1 Understanding interactions with other users: navigation, recreational boating, commercial fishing, etc.	Yes, relevant to all tidal lagoon projects	No
Theme 5: Policy and Regulation			
8. Policy and Legislation	8.1 Lack of overarching National Policy Statement and lack of a strategic approach for Tidal Range Technology	Yes, relevant to all tidal lagoon projects	**Yes**
8. Policy and Legislation	8.2 Lack of integration/streamlining across different Directives e.g. projects that are likely to invoke Imperative Reasons of Overriding Public Interest (IROPI) under the requirements of the Habitats Directive and Article 4.7 under the Water Framework Directive	Not at current scale of sectors	No
8. Policy and Legislation	8.3 Further consideration is needed with respect to how schemes of the scale and nature of tidal range developments align with the principles of sustainable development. Specifically, there is a requirement to ensure that socio-economic assessments undertaken as part of EIA's consider an agreed set of factors and use consistent methods of assessment. This will enable the development of a quantitative assessment approach to determining water costs (ecosystem services) vs. sustainable development vs combating climate change.	Not at current scale of sectors	No
9. General	9.1 Development of guidance and policy around Adaptive Environmental Management Plans. To include review of; - use of lead (not lag) criteria - use of advisory panels including key stakeholders - setting clear objectives - disclosure of data - cost and liabilities	Yes, relevant to all tidal lagoon projects	**Yes**
9. General	9.2 Possible need for whole system R&D to underpin the development pathway to sustainable tidal lagoon development, long term ecosystem health and well-being of populations.	Yes, relevant to all tidal lagoon projects	No
9. General	9.3 Potential for using Regional Environmental Assessment (REA) approach for areas defined supporting multiple lagoon developments with individual EIAs using the regional-scale data (as done for marine aggregate industry)	Yes, relevant to all tidal lagoon projects	No

Topic	EIA/HRA issue	Strategically relevant?	Current key strategic consenting issue?
10. WFD	10.1 Development of tools and methodologies to determine thresholds for acceptable change, particularly for WFD biological elements and agreement on the use of these tools with Regulatory Authorities.	Yes, relevant to all tidal lagoon projects	**Yes**
10. WFD	10.2 Guidance needed on the information requirements to inform the 'Significantly Better Environmental Options' WFD 4.7 Derogation test	Yes, relevant to all tidal lagoon projects	**Yes**
10. WFD	10.3 Development of a Cost/Benefit Analysis tool to assign a quantitative/monetary approach to the cost of deterioration in the context of a WFD water body and 4.7 derogation tests.	Yes, relevant to all tidal lagoon projects	No
10. WFD	10.4 Agreed procedures are needed for the physical process assessment approach(es) to inform EIA/HRA/WFD assessment requirements.	Yes, relevant to all tidal lagoon projects	No
10. WFD	10.5 Need to agree standard approach to fish impact assessments i.e. approach to assessing against WFD, eels regs etc.	Yes, relevant to all tidal lagoon projects	**Yes**
11. Decommissioning	11.1 Development of guidance on information requirements for decommissioning at project application stage.	Yes, relevant to all tidal lagoon projects	No
11. Decommissioning	11.2 Models or approaches for predicting future status of the environment and effects over the very long term.	Yes, relevant to all tidal lagoon projects	No

5.2 TIDAL LAGOONS- IDENTIFICATION OF PROPOSED PRIORITY RESEARCH PROJECTS

A screening process has been undertaken to identify an initial list of high priority research projects for the tidal lagoon industry. The list of proposed high priority strategic research projects identified to address key strategic consenting issue of tidal lagoon developments is shown in Table 5.2. **Note that this list is a starting point for discussion**.

The same selection criteria has been used here as per that of Section 2 for wave and tidal current projects to identify a prioritised list of research projects for tidal lagoon developments. See below for description of the selection criteria used:

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 tidal range sector.
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.

Table 5.2 High priority strategic research projects identified to address key strategic consenting issues of tidal lagoon developments

Theme	EIA/HRA Issue	Potential Project Title / ORJIP comment on potential project
Physical Processes (Impact Assessment)	1.2 The need to (a) collate and evaluate the efficacy of available modelling tools and other assessment techniques to predict near and far-field and medium to long-term morphological changes arising from single or multiple tidal range developments and (b) innovate and develop existing models as well as improve capabilities with regards to application of such modelling tools. 1.3 Understanding and predicting changes to physical processes (hydrodynamics including tidal and wave characteristics, sediment dynamics, geomorphology) in an estuary/system, as a result of schemes, both near and far field (plus associated indirect loss and changes to habitats and species). Need to agree procedures to define study boundaries and appropriate grid resolution for single or multiple tidal range developments. 1.9 Need to ensure that discussion undertaken and consensus reached between industry and regulators on the key assumptions that should be used to inform existing models used to better understand the compounding effect of projected Sea Level Rise (SLR) on other pressures and impacts. In particular changing tidal levels, shifting habitats (in response to extreme events) in-combination with the impacts of project-level developments themselves.	**Good Practice Guidance on Assessing Physical Processes, Water Quality and Flood Risk Aspects of Tidal Lagoon Developments** There is a need to develop guidance on best methods and tools to enable a holistic approach to assessment of physical process issues (geomorphology, sediment transport etc.), water quality and flood risk in relation to tidal lagoon developments. A potential project could aim to; • Develop guidelines or standards for baseline characterisation (e.g. wave climate, currents, water levels, suspended sediment concentration, seabed sediments) and types of analyses (including timescale, resolution and accuracy requirements). • Review the available modelling tools used to assess such impacts and provide a critical review of them/recommendation on best tool(s) for the issue in question (to avoid lack of consistency between various models and the subsequent need to calibration and validation of different models); • Collate input from key regulatory bodies on this issue which would greatly benefit future EIA and consenting. • Aim to identify shortcomings in existing tools and make recommendations of where innovation and development could be used to modify existing and/or develop new tools; • Define appropriate study boundaries and grid resolution for such tools (1.7) and provide guidance on approach to physical process assessment that would inform EIA/HRA and WFD requirements (1.8). • Consider methods for incorporating impacts of predicted SLR and changes in wave climate and defining key assumptions to be used. Without such guidance, new, future projects may all adopt different principles and methods of assessment and the debate will be as much about the validity/suitability of the tools used as the actual outputs used in the subsequent assessment process which should be the focus of discussions between developers and stakeholders.

Theme	EIA/HRA Issue	Potential Project Title / ORJIP comment on potential project
Fish (EIA Characterisation Data)	3.1 Need for increased understanding for all stages of the life cycle of key diadromous and marine fish species (each species would have the opportunity to interact with a tidal lagoon at least twice, as a juvenile and an adult). 3.2 Need for increased understanding and data on the migratory routes of diadromous fish (particularly eel, lamprey, shad and salmon) and on habitat utilisation of these species within or adjacent to proposed lagoon developments. Need to develop methods to gather such information. These data are needed to inform fish modelling work and to verify parameters used in Individual Based Modelling (IBM)). 3.3 Review and recommendations for appropriate and proportionate objectives and methodologies for fish characterisation surveys to inform EIA / HRA /WFD (study should also list all existing programmes and data (e.g. Instituut voor Natuur- en Bosonderzoek – INBO) and investigate scope for a data sharing network to be established. 3.4 Development of agreed methodology to identify and quantify fish population modelling parameters and key data requirements for species of concern. 3.7 Development of fish tagging/tracking technology (and correct methods of obtaining and handling sufficient numbers of fish) to provide suitable data to inform modelling and EIA work needed for lagoon projects. To include technology suitable for use on juvenile fish.	**Good Practice Guidance on Methods and Criteria for Collecting Fish Data to inform EIA for Tidal Lagoon Developments** There is a need to improve evidence on the ecology, behaviour and life histories of key species likely to utilise areas and habitats within, or impacted by, lagoon developments. To address these gaps, there is a need to better define and agree approaches to gathering suitable, relevant and robust data on fish to inform subsequent EIA/HRA/WFD assessment (and specific fish impact modelling). Whilst it is apparent that technologies and tools already exist, guidance on how these best be used in the context of tidal lagoon projects (EIA/HRA/WFD) is lacking. A potential project could aim to cover the following elements; • Guidance on key data needed to inform impact assessments for marine and migratory fish populations • Review of existing relevant data sets to examine if they can provide the necessary information to determine potential changes at population-level and if changes are detected, whether these can be attributed to specific projects • Review of tools/methods available to collect these data (including specific guidance on methods of capture and tagging for specific species and life-stages) • Review of existing tagging/tracking studies/programmes and review of available data • Advice on timeframes and spatial extent of project-specific data collection required to inform EIA/HRA/WFD • Guidance on how these data should be used to inform fish impact assessments • Overview of data limitations

Theme	EIA/HRA Issue	Potential Project Title / ORJIP comment on potential project
Fish (Impact Assessment)	3.5 Development of existing or new tools and approaches for stock assessment and population level impact assessment for key marine and diadromous fish species. Impact thresholds must be realistic, i.e. can actually be detected via available monitoring techniques. 3.6 Development of tools / agreed approaches for assessing the economic value of river/estuarine/coastal fisheries (commercial/recreational/heritage). 3.8 Understanding the potential synergistic and/or cumulative effects of (construction) contaminants on fish and prey species. 3.9 Understanding the effects of construction / operational turbine noise on hearing ranges for key fish species (and risk of barrier effect) and whether this results in avoidance. 3.10 Development of a lagoon-specific fish collision modelling approach that is accepted across industry and regulators. 3.11 Understanding the risk of (i) multiple turbine passes and risk of re-entrainment and (ii) sub-lethal damage and development of appropriate or novel modelling and assessment tools. 3.12 Need to increase understanding of the responses of fish to changes in migratory cues as a result of tidal range developments. 3.13 Need to increase understanding of the impact of physical barriers and constrained tidal flow on diadromous fish species utilising estuaries within impounded areas, i.e. is migration upstream and downstream hindered by change in tidal flows/delays in passage.	**Good Practice Guidance on Methods of Impact Assessment for Fish Ecology in relation to Tidal Lagoon Developments** There is a need to develop models or tools to predict impact pathways, magnitude and significance for key fish species and populations. A potential project could aim to cover the following elements; • Guidance on key data needed to inform fish impact assessments (would be potentially taken direct from previous Project Output, i.e. "*Good Practice Guidance on Methods and Criteria for Collecting Fish Data to inform EIA for Tidal Lagoon Developments*" • Review and critique of existing tools/methods available for fish impact modelling and assessment, including life cycle models • Development of agreed criteria/assumptions for modelling • Investigate potential methods to validate existing models • Development of an agreed, standardised approach to fish impact assessment • Propose thresholds of effect over which significant impacts would arise in context of EIA/HRA and WFD (noting that different criteria and assessment methodologies would need to be applied in the context of WFD • Development of impact criteria and methods to detect changes via monitoring, e.g. use of power analysis

Theme	EIA/HRA Issue	Potential Project Title / ORJIP comment on potential project
Fish (Impact Assessment)	3.7 Development of fish tagging/tracking technology (and correct methods of obtaining and handling sufficient numbers of fish) to provide suitable data to inform modelling and EIA work needed for lagoon projects. To include technology suitable for use on juvenile fish. 6.8 Need to increase understanding of options for mitigation and monitoring strategies for marine/estuarine and freshwater diadromous fish (including noise/light deterrents). 6.2 Understanding / addressing conflicts between need for compensation habitat creation and other statutory obligations (e.g. designated sites). Offset should not contradict or compete directly with other offset requirements (e.g. Shoreline management plan compensation). 6.3 Develop agreed set of options and principles for creation of compensation habitat, particularly for features that cannot easily be created. 6.4 Agree standard set of "success criteria" for compensation habitat measures. 6.5 Development of novel / emerging technologies tools and methods for monitoring long-term changes in mudflat levels /morphological changes, i.e. X-Band Radar, Satellite imagery, drone imagery, and demonstration needs for routine applications. 6.6 Understanding the feasibility, likely effectiveness of habitat translocation / re-creation and development of innovative approaches as mitigation/compensation measures.	**Review of effective and suitable mitigation and monitoring strategies for marine/estuarine and freshwater diadromous fish in relation to tidal lagoon developments** Measures to mitigate impacts on key fish species and populations are likely to play key roles in consenting processes for tidal lagoon developments and need to be better understood. A potential project could aim to cover the following elements; • Guidance on what constitutes mitigation in the context of fish impacts, e.g. for population level impacts, does improved access to spawning grounds through barrier removal act as a form of mitigation? • Guidance on fish mitigation measures that could be "built-in" at the early design stage of tidal lagoon developments • Guidance on approach to mitigation and compensation for mobile species specifically for HRA and WFD (recognising that measures implemented that are not within the water body or SAC potentially affected will not only benefit that particular catchment but will have wider positive effects on mobile populations) • Review of issues related to mitigation of effects in individual water bodies or SAC's far from the project and consequent technical feasibility and economic factors • Review of tools/measures available to mitigate potential impacts on fish (to include visual and acoustic deterrents, habitat improvements, barrier removals/improvements, community schemes, fishing management areas etc.) • Review of methods and techniques of monitoring potential fish impacts (hydro-acoustic, cameras, tags etc) and using the outputs of any monitoring in an adaptive management framework to implement mitigation measures where needed • Review of existing monitoring data sets to examine if they can provide the necessary information to be used to examine change in populations and how if negative effects (against agreed criteria) are identified they could be attributed to a project

6 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 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.

7 APPENDICES

APPENDIX A HIGH PRIORITY STRATEGIC RESEARCH PROJECTS WITH CONSIDERABLE RESEARCH UNDERWAY/PLANNED

Topic	Recommended research project and key consenting issue	Tidal current	Wave
A. Collision risk	A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA **Relevant key issue(s):** • 1.1 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain • 1.2 The nature of any interactions between diving birds and tidal turbines is uncertain • 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 • 5.6 Better understanding of population level impacts and methods to assess the significance of population level impacts would improve confidence in EIA/HRA **Current status:** **Recently completed project(s):** • SNH has published guidance on Collision Risk Assessment of Marine Wildlife with Tidal Turbines. This is a review of 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). Scottish Natural Heritage (2016) 'Assessing collision risk between underwater turbines and marine wildlife'. SNH guidance note. Available at: http://www.snh.gov.uk/docs/A1982680.pdf • Marine Scotland/SNH have completed the project Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines (Band, Sparling, Thompson, Onoufriou, San Martin & West, 2016. Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines. Scottish Marine and Freshwater Science, Volume 7, Number 17. Available online: http://www.gov.scot/Resource/0050/00509891.pdf) • 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. Paper available at https://www.researchgate.net/publication/319311507_Algorithms_for_marine_mammal_modelling_and_an_application_in_Ramsey_Sound and in Proceedings of EWTEC 2017 (http://www.ewtec.org/proceedings/. Model available on request from Thomas Lake t.lake@swansea.ac.uk	✓	X

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	Relevant projects currently planned or underway: • Ongoing: Marine Scotland/ SNH: Scottish Government Demonstration Strategy Phase 2 - Monitoring around the first devices deployed at MeyGen. Phase 1 now complete: Trialling methods for tracking the fine-scale underwater movements of marine mammals. This is the package of in-situ monitoring equipment deployed around the MeyGen turbines in Inner Sound, Phase 1 report available: http://www.gov.scot/Resource/0050/00501574.pdf • MeyGen Knowledge Transfer Partnership (KTP) with University of Aberdeen (February 2015 – January 2017) Dr Beth Scott and Benjamin Williamson KTP Associate		
A. Collision risk	A.5 Studies to investigate behaviour and use of tidal areas by marine mammals and basking sharks **Relevant key issue(s):** • 1.1 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain **Current status:** SMRU are currently investigating tagging data from a number of tidal sites with a view to assessing the generalities of these findings and how they should be applied in future assessments. Also work underway for the Scottish Government Demonstration Strategy at MeyGen involves tagging of harbour (common) seals to look at movement and behaviour of animals in relation to the MeyGen site. **Recently completed project(s):** • Macaulay, J., Malinka C., Coram, A., Gordon J. & Northridge, S. (2015). The density and behaviour of marine mammals in tidal rapids. Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, no. MR 7.1.2., St Andrews, 53pp • Macaulay, J., Gordon, J., Coram, A., Northridge, S. (2015) Quantifying porpoise depth distributions and underwater behaviour in tidal rapids areas Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, no. MR 7.1.1., St Andrews, 12pp. **Relevant projects currently planned or underway:** • Scottish Government Demonstration Strategy • SEACAMS2 Assessing the impact of the experimental DeltaStream tidal energy unit in Ramsey Sound (Pembrokeshire) on grey seals movements and energy expenditure. Seals will be tagged to monitor and reproduce 3D movements, behaviour and energy expenditure, using novel high-tech GPS-enabled 'Daily Diary' bio-logging devices developed by Swansea University.	✓	X

Topic	Recommended research project and key consenting issue	Tidal current	Wave
B. Underwater noise	B.3 Gather acoustic data around single operational machines **Relevant key issue(s):** • 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 **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. This work will help identify need/scope for further research. **Relevant projects currently planned or underway:** • Acoustic Monitoring of Wave Energy Converters (Dr Brian Polagye University of Washington). Ongoing acoustic monitoring and methods development for wave energy converters at the US Navy Wave Energy Test Site (Hawai'i, US) in conjunction with University of Hawaii and Sea Engineering. Deployment of bottom mounted, mid-water, and drifting instrumentation packages. • Observations of sound from Northwest Energy Innovations (NWEI) Azura and Fred Olsen Lifesaver at the US Navy Wave Energy Test Site in Hawaii (January 2015 – ongoing) and will include additional WECs). EWTEC paper submitted. Conference presentation in June 2017 at ASA. Brian Polagye **Dataset available:** • Representative acoustic data from NWEI Azura and Fred Olsen Lifesaver (drifting and stationary measurements at up to 200 kHz resolved frequencies) at the US Navy Wave Energy Test Site. (data annotation underway)	✓	✓
E. General	E.6 Establish appropriate and proportionate objectives and methodologies for site characterisation surveys to inform EIA/HRA **Relevant key issue(s):** • 5.4 An agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA is required	✓	✓

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	Current status: • 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. **Recently completed project(s):** • RiCORE Project has now been completed. (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. The results can be found here: http://ricore-project.eu/downloads/ • NRW Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales (Sparling C, Smith K, Benjamins S, Wilson B, Gordon J, Stringell T, Morris C, Hastie G, Thompson D & Pomeroy P 2015: Guidance to inform marine mammal site characterisation requirements at wave and tidal stream energy sites in Wales NRW Evidence Report Series Report No: 82, 87pp, Natural Resources Wales, Bangor. 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. Marine Scotland's Survey, Deploy & Monitor Policy was reviewed and version 2 was published in April 2016. Available here: http://www.gov.scot/Topics/marine/Licensing/marine/Applications/SDM **Relevant projects currently planned or underway:** • NERC-funded VertIBase (April 2016 – March 2018) - Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy technologies. Lead Research Organisation: Cranfield University • SEACAMS2 Review of current data requirements for assessing risks from a MRE development to marine mammals in Wales. The study will explore the consenting process for previous projects (where available) to assess to what extent baseline data collection requirements have been met and whether using existing datasets could fulfil the current regulatory requirements. • Joint NRW project with NE on development of sonar camera for surveying *Sabellaria* reef in the Severn Estuary - developing non-invasive tools for accurate detection of biogenic reefs in low visibility highly dynamic environments. Lead contact Maria Alvarez, Natural England maria.alvarez@naturalengland.org.uk • Marine Scotland/SNH - Development of a Power Analysis Tool. The aim of this study is to design a software package that can be used by non-specialists to aid design of monitoring studies that have sufficient power for use in assessing impacts. • Marine mammal survey work off North Anglesey: Bangor University undertaking double platform boat-based transect surveys of combined Morlais and Minesto project area to assess methods for calculating absolute density and provide estimates for use in EIA.		

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	• 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 lagoon projects, some of the principles are likely to also be relevant for wave and tidal current projects.		
F. Regulatory issues	F.3 Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays **Relevant key issue(s):** 10.3 Agreement is required on the approach to applying a design envelope approach to consenting wave and tidal arrays 10.5 Further guidance is required as to how best to consider decommissioning in the consenting process. **Current status:** ORJIP Ocean Energy (with support from regulators and SNCBs) has plans to organise and facilitate a workshop on project design envelopes to help inform guidance on best practice. The outputs from this workshop will be used to produce a position paper on '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'. The position paper will include 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. The position paper will also include guidance as to how to best ensure that all options and processes associated with decommissioning are included from the outset of a project. **Recently completed project(s):** • Project by NRW[3] - 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. 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. Due to finish by the end of the financial year 2016/2017. Results will be presented in two reports; one principles document for open dissemination and another with more detailed info on Morlais and proposed	✓	✓

[3] Supported by Project Steering Group composed of Morlais, SEACAMS, NRW Operations, NRW Licensing

Topic	Recommended research project and key consenting issue	Tidal current	Wave
	activities (used to identify the principles). This will be shared once Morlais consent application is in the public domain. • 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).		
F. Regulatory issues	F.6 Methods are required for determining connectivity of mobile qualifying species from protected sites with development areas **Relevant key issue(s):** • 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 **Current status:** There is a substantial amount of work currently underway to investigate connectivity of mobile qualifying species from protected sites and potential development areas (see below). The findings of these studies will inform the need/scope for any future research in this area. **Relevant projects currently planned or underway:** • The River Dee Trust, Aberdeenshire, and Marine Scotland Science - Salmon and sea trout tracking array. The aim is to determine the migration routes of salmon and sea trout by tracking the movement of these fish from the rivers Dee, Don and Ythan for Vattenfall's European Offshore Wind Deployment Centre (EOWDC). Tagging will commence in 2018. • JNCC leading work to look into producing guidance for marine mammal management units. Lead contact Sonia Mendes JNCC Sonia.Mendes@jncc.gov.uk • SMRU Consulting and the University of St Andrews - Improving understanding of bottlenose dolphin movements along the east coast of Scotland (2017 – 2019). • MacArthur Green, Glasgow - Tracking guillemots and razorbills. Initial deployment of the tags is planned for the summer of 2017 with recoveries carried out a year later. This should mean maps of migration routes from different colonies would be available in late 2018.	✓	✓

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

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

Topic	EIA/HRA issue	Relevant to wave or tidal current?	Strategically relevant?	Commercial or demonstration scale?	Iteration of F.L that issue was demoted	Current key strategic consenting issue?
Human environment						
Impacts on seascape	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	Version 3	Not considered to be a key strategic consenting issue as this issue is not relevant to all projects.
Impacts on seascape	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	Version 3	Not considered to be a key strategic consenting issue as this issue is not relevant to all projects.
Regulatory						
Regulatory processes	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	Version 3	This issue has now been addressed
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	Version 2	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.

Topic	EIA/HRA issue	Relevant to wave or tidal current?	Strategically relevant?	Commercial or demonstration scale?	Iteration of F.L that issue was demoted	Current key strategic consenting issue?
Underwater noise	Agreed approaches for measuring noise from operational devices and construction activities are required	Both	Yes, relevant to all projects	Demonstration and commercial	Version 2	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	Version 2	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	Version 2	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	Version 2	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 however there is a greater risk for large baleen whales due to their size and foraging habitats.[4] This is no longer considered to be key strategic consenting issue.

[4] http://www.snh.org.uk/pdfs/publications/commissioned_reports/791.pdf

Topic	EIA/HRA issue	Relevant to wave or tidal current?	Strategically relevant?	Commercial or demonstration scale?	Iteration of F.L that issue was demoted	Current 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	Version 2	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.[5] 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	Version 2	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	Version 2	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	Version 2	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	Version 2	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 basking sharks	Both	No, site/project specific	Demonstration and commercial	Version 2	Not considered to be a key strategic consenting issue.

[5] 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?	Iteration of F.L that issue was demoted	Current key strategic consenting issue?
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	Version 2	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	Version 2	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	Version 2	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	Version 2	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	Version 2	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	Version 2	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	Version 2	Not considered to be a key strategic consenting issue. Any mitigation measures would be entirely site and project specific.

Topic	EIA/HRA issue	Relevant to wave or tidal current?	Strategically relevant?	Commercial or demonstration scale?	Iteration of F.L that issue was demoted	Current key strategic consenting issue?
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	Version 2	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.
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	Version 2	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	Version 2	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	Version 2	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	Version 2	Not considered to be a key strategic consenting issue.

APPENDIX C WAVE AND TIDAL CURRENT: RESEARCH GAP ANALYSIS AND RESEARCH RECOMMENDATIONS

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. Projects for which there is considerable research currently underway to address the issue are categorised as on 'HOLD' (see Appendix A).

Key Issue	Gaps identified	Research area	Priority
Collision risk			
1.1 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: • 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	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. 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).	High Project A.1 Near-field monitoring of marine mammals around operational tidal turbines and first arrays to inform collision risk assessment 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
1.1 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: • 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	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

Key Issue	Gaps identified	Research area	Priority
1.1 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: • 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
1.1 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: • 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	• 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

Key Issue	Gaps identified	Research area	Priority
1.1 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 assessment for marine mammals and basking sharks.	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD
1.1 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	Improvements in input parameters for collision risk models is required	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD
1.1 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain	Use of tidal streams by marine mammals and basking sharks: • 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. Also studies 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.	High Project A.5 Studies to investigate behaviour and use of tidal areas by marine mammals and basking sharks HOLD

Key Issue	Gaps identified	Research area	Priority
1.1 The nature of any potential interactions between marine mammals and basking sharks and tidal turbines is uncertain	Use of tidal streams by marine mammals and basking sharks: • 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)	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).	High Project A.5 Studies to investigate behaviour and use of tidal areas by marine mammals and basking sharks HOLD SMRU are currently investigating tagging data from a number of tidal sites with a view to assessing the generalities of these findings and how they should be applied in future assessments.
1.2 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: • 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

Key Issue	Gaps identified	Research area	Priority
1.2 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: • 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
1.2 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: • 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
1.2 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: • 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	• 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

Key Issue	Gaps identified	Research area	Priority
1.2 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: • 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
1.2 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 assessment for diving bird species.	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD
1.2 The nature of any potential interactions between diving birds and tidal turbines is uncertain	Assessing collision risk for diving birds.	Improvements in input parameters for collision risk models is required	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD

Key Issue	Gaps identified	Research area	Priority
1.2 The nature of any potential interactions between diving birds and tidal turbines is uncertain	Use of tidal streams by diving birds: • 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)	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
1.2 The nature of any potential interactions between diving birds and tidal turbines is uncertain	Use of tidal streams by diving birds: • 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
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: • 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

Key Issue	Gaps identified	Research area	Priority
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: • 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
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: • Probability of occurrence	Individual Based Models (IBMs) can be used to investigate emergent behaviours of groups of animals.	Low
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: • 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
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: • 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 • 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)	Low
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 assessment for migratory fish species.	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD

Key Issue	Gaps identified	Research area	Priority
1.3 The nature of any potential interactions between migratory fish and tidal turbines is uncertain	Assessing collision risk for migratory fish	Improvements in input parameters for collision risk models is required	High Project A.4 Further development in approaches to collision risk assessment for marine mammals , fish and birds to inform EIA/HRA HOLD
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 *et al*., 2013): • Migratory pathways / behaviour – to what extent are migratory salmonids likely to be geographically co-incident with the locations of wave and tidal energy projects • 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?	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 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

Key Issue	Gaps identified	Research area	Priority
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	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. 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 a 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).	High Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals
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	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 can be used to find effects on key marine species and their prey.	High Project A.2 Further research to help understand the possible likelihood, probability and consequence of collision with tidal turbines for marine mammals
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	Development and trialling of technologies such as active sonar, underwater cameras, high resolution telemetry and other methods. Demonstrable capacity to track species movement. Development of cost-effective and appropriate long-term PAM and tracking. Static bottom-mounted hydrophone arrays Use of x-band radar, tagging systems or other	High Project E.3 Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays

Key Issue	Gaps identified	Research area	Priority
		methods to quantify the 3-dimensional movements of diving birds/fish to provide insight into the responses to tidal devices. Trial/test monitoring technologies (potentially at e.g. EMEC, WaveHub, FaBTest and other test sites) to inform improvements in technologies and cost reductions	
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	Development and trialling of technologies such as active sonar, underwater cameras, high resolution telemetry and other methods. Demonstrable capacity to track species movement.	High Project A.3 Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays
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 , and • Detect and record actual collision events to quantify the incidence/frequency of collisions	Comparison of methods for monitoring especially as scaling up from single devices to arrays.	High Project A.3 Further development of instrumentation and methodologies for detecting potential collision events around tidal turbines and arrays Project E.3 Further development of instrumentation and methodologies for monitoring wildlife behaviour around tidal turbines and arrays

Key Issue	Gaps identified	Research area	Priority
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 , 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.	High Project E.2 Development of mitigation measures for identified and potential impacts of wave and tidal developments
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.	High Project B.3 Gather acoustic data around single operational machines HOLD
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.	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). 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.	High Project B.2 Development of noise propagation models to further reduce uncertainty regarding the potential impacts of commercial scale arrays

Key Issue	Gaps identified	Research area	Priority
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.	High Project B.1 Establishment of an acoustic 'evidence base' for 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	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
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
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

Key Issue	Gaps identified	Research area	Priority
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
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
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.	Low
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.	High Project C.1 Development of an agreed approach to assessing the potential effects of displacement from wave and tidal arrays

Key Issue	Gaps identified	Research area	Priority
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
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 due to tidal projects. To enable Regulators to assess the risk.	Medium
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
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

Key Issue	Gaps identified	Research area	Priority
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
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 Note recently commissioned project: The River Dee Trust, Aberdeenshire, and Marine Scotland Science - Salmon and sea trout tracking array (2018 - ?). Aim is to determine the migration routes of salmon and sea trout by tracking the movement of these fish from the rivers Dee, Don and Ythan for Vattenfall's European Offshore Wind Deployment Centre (EOWDC).
5.4 An agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA is required	No agreed approach to undertaking site characterisation and baseline surveys for marine mammals and birds to inform EIA and HRA	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
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

Key Issue	Gaps identified	Research area	Priority
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
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 Note: JNCC leading work to look into producing guidance for marine mammal management units. Lead contact Sonia Mendes JNCC Sonia.Mendes@jncc.gov.uk
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

Key Issue	Gaps identified	Research area	Priority
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
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
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.	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 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

Key Issue	Gaps identified	Research area	Priority
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		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
Social and economic impacts on local communities			
8.1 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.	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. 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, particularly during the construction phase.	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

Key Issue	Gaps identified	Research area	Priority
8.1 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
8.1 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)	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. A review of work underway in offshore wind ORJIP could be adapted / aligned with the needs of the wave and tidal industry.	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
8.1 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

Key Issue	Gaps identified	Research area	Priority
Impacts on physical processes			
9.1 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
9.2 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 Population Viability Analysis (PVA)/Potential Biological Removal (PBR). Review of PBR approach to regulation including a consideration of alternatives. Briefing paper for Regulators and developers.	High Project F.1 Review of Potential Biological Removal (PBR) approach to regulation including consideration of alternatives
10.1 Method/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	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 environmental risks associated with wave and tidal energy developments within the consenting process

Key Issue	Gaps identified	Research area	Priority
10.2 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
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.	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. 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 out with the breeding season. E.g. Understanding linkages between migratory salmon (Natura species) and SACs. How to apportion populations to rivers and SAC sites. E.g. Understanding connectivity of marine mammals from SACs and development areas	High Project F.6 Methods are required for determining connectivity of mobile qualifying species from protected sites with development areas HOLD

Key Issue	Gaps identified	Research area	Priority
10.3 Agreement is required on the approach to applying a design envelope approach to consenting wave and tidal arrays			High Project F.3 Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays. HOLD
10.4 Agreement is required on the approach to developing Project Environmental Monitoring Plans, incorporating adaptive management strategies, for commercial scale wave and tidal arrays			High 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.
10.5 Further guidance is required as to how best to consider decommissioning in the consenting process.			High Project F.3 Development and agreement of methods/processes for implementing a design envelope approach to consenting wave and tidal arrays. HOLD