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environmental services and products

A review of the potential impacts of wave and tidal energy development on Scotland's marine environment

Cover report

Report to: Marine Scotland

Issued by: Aquatera Ltd

In collaboration with:

Environmental Research Institute
European Marine Energy Centre Ltd
International Centre for Island Technology,
Heriot Watt University
SMRU Marine Ltd

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1 Introduction

1.1 Background

The Scottish Government has set a target for meeting 100% of Scottish demand for electricity from renewable energy sources by 2020. Plans are developing to ensure that marine renewable energy sources, including wave, tidal current and offshore wind, will make a full contribution to meeting this target[1]. As with any type of industrial development, there are a number of potential impacts that may arise, including environmental, economic and social impacts.

In 2009, Aquatera and its collaborative delivery team were appointed by the Scottish Government to undertake a study to 'review the potential impacts of marine energy devices on Scotland's marine ecological environment'. The team brought together by Aquatera consisted of leading specialists from Aberdeen University, the European Marine Energy Centre (EMEC), the Environmental Research Institute (ERI), the International Centre for Island Technology (ICIT), Robert Gordon University, the Scottish Association for Marine Science (SAMS) and the Sea Mammal Research Unit (SMRU) Ltd.

The main objectives of this study were to:

- Identify the key technical components associated with wave and tidal energy development
- Identify those marine species and habitats that are potentially sensitive to the development of marine energy in Scotland
- Identify potentially significant interactions and key issues for marine ecology arising from the development of marine energy in Scotland
- Provide recommendations around strategies for key issues including, strategic and project level baseline and monitoring studies, adaptive management policies etc.

The major concern within the team at the outset of the initial project was the lack of real data and information regarding the effects of wave and tidal energy developments on the marine environment and therefore, the ability to meet these objectives. This is a nascent industry that has seen relatively few 'at-sea deployments', and there has been little opportunity to monitor or investigate the impacts of the various technology types, moorings etc. on the marine habitats and species of Scotland and indeed around the world.

However, members of the team have been involved, in a broad range of capacities, in numerous aspects of predicting and monitoring environmental impacts and risk associated with proposed wave and tidal deployments (a number of which are now installed) including: ecological and technical baseline surveys; environmental impact assessments; monitoring of existing installations; and other industrial activities in Scotland's seas. The Project Team was and remains acutely aware of the need to understand the potential effects so as to identify those that may be of immediate concern and to identify those that are not.

Therefore the team concluded that these objectives could be met by a high level assessment of the potential effects informed by existing information regarding species, habitats and technology types, along with the expertise and subjective opinions of the team and that this assessment should be updated as new and better information and data become available.

The initial project involved an assessment process that considered some 29,329 interactions associated with wave and tidal energy development in Scotland. Due to the large volume of data and

[1] Marine Scotland – Topic Sheet No.26 v1

information generated during the project, it was decided early on that the main outputs should be presented within a framework which is fully transparent and can be easily updated as and when new information becomes available.

Following further assessment, 19 potential 'key issues' were identified. Strategies for addressing each of these in relation to single device deployments and demonstration scale arrays were then developed. It was envisaged that these strategies would facilitate early discussions between developers, regulators and stakeholders to scope any environmental assessments and monitoring programmes required for a particular wave or tidal energy project in Scotland.

Following completion of this initial study, Aquatera was commissioned by The Scottish Government to develop a project website which provided access to the reports produced during the initial study. The website also included access to the Impact Assessment Tool which developers and stakeholders could use to; interrogate the results of the initial study, generate project specific outputs and access the results and recommendations produced during the initial study. The website can be found here: http://www.scotland.gov.uk/Topics/marine/Licensing/marine/tool

In 2013, The Scottish Government commissioned Aquatera to undertake an initial review of the Impact Assessment Tool. Aquatera assembled a team of leading experts to undertake this study which included:

- Environmental Research Institute (ERI);
- European Marine Energy Centre (EMEC);
- International Centre for Island Technology, Heriot Watt University (ICIT); and
- SMRU Marine Ltd.

1.2 Study aims

As stated previously, the main objectives of the initial study were to identify and prioritise the potential key issues associated with the development of wave and tidal energy and Scotland's marine ecological environment and to develop suitable strategies for addressing these issues in the immediate future.

The main objectives of the 2014 review were to:

- Initiate a first review of the project information, assessment results and recommendations, identifying areas that require new material and identifying programmes to deliver this data/information;
- Update the assessment tool and its recommendations as appropriate; and
- Establish procedures and guidance for future reviews of the project information, assessment results and recommendations.

Note: proposed procedures and guidance for future reviews will be developed following this initial consultation period.

1.3 Approach to the study

The approach undertaken during the 2014 review is presented in the following table along with the relevant outputs. The approach and results are described in further detail in Sections 2 to 7 of this report.

Task	Approach	Output
Task 1 – review and update of Impact Assessment Tool inputs	A comprehensive review of the following Impact Assessment tool inputs used during the initial study was undertaken: • Annex I – Guide to technical components relevant to wave and tidal energy • Annex II – Guide to habitats and species relevant to wave and tidal energy Following this review, these inputs were updated and revised as necessary and new versions produced.	Updated Impact Assessment Tool and supporting information (Electronic Database, Annexes 1 and 2)
Task 2 – review and update of Impact Assessment Tool results	A comprehensive review of the results from the initial study was undertaken by the team. Following this review, the results were revised and updated as and where necessary based on new research, results from key studies and general better understanding of interactions and technologies. This process included the incorporation of a number of new wave and tidal technologies into the assessment. The tool was fully updated with the new and revised results.	
Task 3 – review and update of the priority key issues	Following the review and update of the assessment results, the list of priority issues was revised accordingly.	
Task 4 – review and update of 'recommendations for addressing potential key issues'	During the previous study, a series of recommendations for addressing the potential key issues were developed. During this initial review, these were updated accordingly.	Updated 'recommendations for addressing potential key issues' (Annex 3)
Task 5 – development of a strategy for regularly updating the online tool	A proposed strategy and procedure for undertaking subsequent regular reviews and updating the IMPACT tool and other study outputs has been developed.	IMPACT Review Strategy

The outputs updated/generated during the 2014 review have a range of applications and can be utilised by a number of end users. The possible applications for the key study outputs (electronic database, strategies for addressing key issues and supplementary information guides) are presented in the following table by potential end user:

Table 1.1 Study outputs and end users

End user	Electronic database	Strategies (Annex 3)	Supplementary information (Annexes 1 & 2)
Regulator(s) and other stakeholders	To identify the key issues associated with any particular development type. To validate submissions.	To develop project specific EIA methodologies, baseline characterisation and impact monitoring plans. To identify areas where targeted strategic research could be undertaken to reduce uncertainty and answer key questions.	To inform decision making with regards to potential impacts on a project specific basis.
Project developers	To identify the key issues associated with their projects, to help identify optimal areas for development and to inform project specific EIAs.	To help understand the possible requirements in relation to a project specific consenting process and to enable comparisons to be made between areas of varying sensitivity.	To inform EIA and consultation with stakeholders.

1.4 Boundaries and limitations

During the initial study the team and project steering group decided that focus should be placed on the potential impacts arising from the different technology types and support structures, as these issues were completely novel to the emerging marine energy industry. This allowed the development of an assessment framework which could then be expanded to include other components of wave and tidal energy development, if deemed appropriate and necessary in the future. It should be noted that additional project components such as support vessel activity, subsea cables (export and interarray) and other infrastructure that may be required to support a project and impacts associated with accidental and unplanned events were not considered during the initial study or this review process. This information could be incorporated into future iterations if deemed appropriate.

1.5 Purpose of the cover report

The following report details the methods applied to each of the tasks outlined in **Error! Reference source not found.**. Excerpts of the outcomes from each stage of the process are provided throughout the report and full versions within a series of appendices (refer to **Error! Reference source not found.**).

This report should be used as a guide to the process and rationale applied throughout the study. All findings and judgements are presented within the appendices, annexes and the online IMPACT database, which should be viewed as 'second generation' outputs from this review process. The report is structured as follows:

- **Section 2 – Identification of technical elements:** provides an overview of the technologies, mooring systems and support structures considered during the assessment.
- **Section 3 – Identification of sensitive habitats and species:** provides an overview of the habitats and species considered during the assessment.

- **Section 4 – Identification of potential interactions:** provides an overview of the process undertaken to identify potential interactions between technologies, mooring systems and support structures and sensitive habitats and species.
- **Section 5 – Assessment of potential significance of identified interactions:** provides an overview of the impact assessment process.
- **Section 6 – Identifying potential key issues:** provides an overview of the potential key issues identified during the impact assessment process.
- **Section 7 – Developing strategies for handling potential key issues:** provides an overview of the framework used to develop and present the proposed strategies.
- **Section 8 – Conclusions and future development:** provides study conclusions and a proposed approach for undertaking subsequent reviews.

2 Identification of Technical Elements

The objective of this task was to establish the technical boundaries of the study and to ensure that the assessment team had the information necessary regarding the technical elements of wave and tidal developments to make informed judgements regarding the potential interactions with the marine environment.

This task generated the following outputs:

- the technical boundaries for the study were established by the identification of the technical elements (technologies, moorings and support structures) that would be assessed; and
- a set of technical guides to the relevant technologies, moorings and support structures was produced.

During the 2014 review, a number of new wave and tidal technologies were added to the study; Archimedes screw, tidal kite and rotating mass. The technical guides were updated to include the most up to date information available regarding each technology, mooring system and support structure.

There are many elements to a single wave or tidal energy project, for example the energy extraction device, anchors, mooring lines, installation vessels, onshore lay down areas etc. It was decided by the Project Team, in line with the views of the Project Steering Group at the Scottish Government, that those technical elements unique to wave and tidal renewable energy that had not been considered previously to any great degree in terms of potential ecological impacts should be the main focus of the study. As a result, support vessels, grid infrastructure (including subsea electrical cables) and ports etc., are not considered within this study. These technical elements are considered routinely during planning and permitting processes and are regularly subject to stringent environmental assessments regularly. Therefore, the potential effects of these elements are relatively well understood and regulated.

It should be noted that there are a number of environmental pressures and impacts on habitats and species relating to these elements that are currently subject to vigorous investigation, for example, the effects of electromagnetic fields (EMF) from subsea cables on migratory fish and the effects of underwater noise from dynamic positioning (DP) vessels on marine mammals. However, as stated previously, it was confirmed at the outset that this study should focus on those technical elements unique to wave and tidal energy so as to identify the issues specifically relating to the technology types and supporting structures concerned. Therefore, whilst the impacts of ancillary structures and activities may in some cases be as, if not more, important that those associated with the different technologies and moorings etc., they are not considered within the current scope of this study.

The first task was to define the boundaries of the study and select which technical elements (technology types, moorings, support structures, etc.) would be considered during the assessment process.

The team consequently determined that the following technical elements would be considered during the assessment process.

- Tidal energy converters;
  - Axial-flow turbine,
  - Cross-flow turbine,
  - Reciprocating hydrofoils,
  - Archimedes screw,
  - Tidal Kite,
- Wave energy converters;
  - Attenuator
  - Rotating mass
  - Point absorber
  - Submerged pressure differential
  - Oscillating wave surge converter
  - Offshore oscillating water column,
  - Shoreline oscillating water column,
  - Offshore overtopping device,
  - Shoreline overtopping device.

- Moorings and support structures;
  - moorings;
    - gravity anchors,
    - embedment anchors,
    - rock anchors,

    } with mooring lines

    - gravity/deadweight anchors,
    - rock anchors,

    } with taut mooring lines

    - gravity/deadweight anchors,
    - rock anchors,

    } with mooring lines and floating pontoons

  - support structures;
    - Gravity base structure,
    - Rock anchors / pinned gravity base,
    - Drilled and Grouted piles,
    - Driven/percussion piles.

Future iterations of this study using the electronic tool created during this project may be developed further to incorporate ancillary elements so as to build a more complete picture of the potential effects from a marine energy project as a whole, i.e. technology, moorings, cables, support vessels, infrastructure etc. Similarly, the tool could be expanded to incorporate terrestrial elements of any development and assess the potential effects onshore, again, building a more complete picture.

For the purposes of this particular study, an outline technical guide to each development element was produced, the aim of which was to provide sufficient outline information to allow environmental assessors within the Project Team to make informed judgements around potential environmental interactions with the marine environment. The type of information gathered for each development element is outlined in Table 2.1 and Table 2.2.

Table 2.1 Information gathered relating to technology types

Topic	Relevance/purpose
General description	To provide an introductory structural description of the device/ moorings/ support structure
Technology examples	List of example devices currently under development (with a focus on devices that have been deployed)
10MW development scenario	
No. of devices	Number of devices likely to be installed within a 10MW array
Array layout and spacing	Likely array configuration and spacing between devices
Seabed footprint	Anticipated footprint of a 10MW installation
Suitable environmental conditions	
Water depth	Bathymetric range at which each technology type could be deployed
Resource	Wave / tidal resource required for each technology type
Components	
Fixed components	Details of any fixed/stationery components i.e. moorings
Moving components	Details of any moving components i.e. blades
Position of components	
Components on the seabed	List of components located directly on the seabed i.e. moorings
Components in the water column	List of components located within the water column i.e. blades
Surface piercing components	List of components located above the water surface i.e. floating support structures

Table 2.2 Information gathered relating to moorings and support structures

Topic	Relevance/purpose
General description	To provide an introductory structural description of the moorings/ support structure
Suitable seabed/geological environmental conditions	Substrate / seabed type suitable for moorings/support structure or seabed type likely to be found in suitable locations
Relative Scale	To provide information on the seabed footprint

The information guides to the wave and tidal technology types as well as their moorings and support structures are presented within Annex I.

3 Identification of Sensitive Habitats and Species

The objective of this task was to define the environmental boundaries of the project and to develop an information base that would ensure that the assessment team would have the information required to make informed judgements regarding the potential impacts of wave and tidal energy developments on the marine environment.

This task generated the following outputs:

- a list of habitats and species for consideration within the assessment process was established; and
- a set of habitat and species guides relevant to sensitivity was produced relating to each species and habitat.

During the 2014 review, the list of habitats and species were reviewed by the project team. Only one species was removed from the study. Yellow-billed diver (white-billed diver) is not on the marine renewables SEA list or on the JNCC list of marine bird species for which marine SPAs in the UK are being considered. It is also a scarce/occasional visitor to UK and therefore the project team removed it from the assessment.

For the remaining habitats and species the list produced during the initial study was deemed to be suitable. The species and habitat guides produced during the initial study (Annexes 1 and 2) were also fully reviewed and updated as necessary by the team.

The project was designed to focus on 'sensitive species and habitats' within Scotland's marine environment. In order to determine which species and habitats would be included, the Project Team drew from a number of existing sources and identified the habitats and species likely to be sensitive to the effects of marine energy developments. These included the species lists used in the previous Marine Renewables Strategic Environmental Assessment [2] and other standard lists. These lists were established by the Project Team and verified/accepted by the Project Steering Group. A total of 12 marine mammal species, 54 bird species, 40 fish and shellfish species and 16 benthic habitats (along with their associated species) were identified for consideration. For a full list of the habitats and species selected for inclusion in the study, refer to Annex 2. It was noted that these lists could be further developed in future iterations to include other habitats and species of concern.

The species and habitats were chosen based on the following criteria:

- Fish and shellfish - Scottish Marine SEA list
- Marine mammals - SNH priority marine species as well as two slightly more offshore cetacean species (as they are common visitors): white-sided dolphins and long-finned pilot whales
- Marine birds - Species list is that used in Scottish Marine Renewables SEA. Herring gull has been split into two separate sub-species 'Scandinavian' and 'Western.' The list used is a complete list of seabirds, seaducks, divers and grebes and includes species whose distributions are entirely coastal and species whose numbers are very low in Scottish waters or limited to occurring over very short time periods. The list includes species on the Scottish

[2] Faber Maunsell and Metoc PLC, 2007. Scottish Marine Renewables Strategic Environmental Assessment (SEA). [online]. Available at: <www.seaenergyscotland.net>

Biodiversity List[3] and the UK BAP list of priority species[4]. The list is also the same as the JNCC list of marine bird species for which marine SPAs in the UK are being considered with the addition of black guillemot (neither Annex I nor migratory).

- Benthic Habitats and Species – EUNIS habitats types which may overlap with potential marine renewable energy sites were included in the assessment, where BAP species occurring in these habitats these were also considered.

In the course of delivery of this contract Scottish Natural Heritage has reviewed a large number of marine habitats and species to identify those considered to be of greatest marine nature conservation importance in Scottish territorial waters - Priority Marine Features[5]. These have been identified in order to focus action, direct research and education and promote a consistent approach to nature conservation advice. All species and habitats included in the Priority Marine Features could be assessed in future iterations of this assessment if appropriate. It should be noted that many of these features were considered as part of this assessment (refer to Annex 2).

The team recognised that it would be beneficial to collate information regarding each habitat and species, which could inform the wider assessment process regarding the potential effects of wave and tidal energy development. To this end, a set of criteria was identified that had the potential to affect the sensitivity of each species and habitat to the environmental pressures associated with the development of marine energy. These criteria are defined within Table 3.1 and Table 3.2.

Table 3.1 Criteria used to assess sensitivity of species

Factor	Definition
Population	Scottish population estimates. UK/European population estimates (breeding/wintering) where appropriate. Population trends: stable/increasing/declining.
Distribution	Spatial and temporal distribution in Scotland: • key areas/habitats (breeding/wintering grounds); and • time of year present.
Status	Legal protection status in Scotland
Life history	Factors that affect recovery times e.g. reproductive strategy, age of maturation, productivity, typical lifespan, adult survival, gestation period, number of pups/clutch size, etc.
Foraging method	Diving depths, propulsion method (wing-propelled/foot-propelled), prey type/species, feeding patterns: nocturnal/diurnal, solitary/gregarious, etc.
Size	Typical size range.
Movement characteristics and sensitivity to disturbance	Aspects of motility: swim speeds, distances covered, sensitivity to disturbance.

3 Scott Wilson, 2005 Production of the list of species and habitats considered to be of principal importance for the purpose of conservation of biodiversity in Scotland (The Scottish Biodiversity List) Part 2 – Technical Report

4 Species listed on the UK Biodiversity Action Plan (UK BAP) list of priority species which identifies species in need of conservation action at a national level using the application of criteria based on international importance, rapid decline and high risk

5 The draft list of Priority Marine Features is available at: http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/priority-marine-features/priority-marine-features/ .

Factor	Definition
Energetics	Migration range, foraging range, moulting period, etc.
Prey/predator detection	Vision, tactile, chemosensory, electro-sensitive, passive listening, echolocation, etc.
Other comments	Research relevant to distribution / behaviour (Marine birds). Extract from JNCC wintering aerial survey Report 333 (Marine birds). Other pressures from fishing etc (Marine fish and shellfish).

Table 3.2 Criteria used to assess sensitivity of benthic habitats and species

Factor	Definition
Description	Description of the habitat and reference to the appropriate EUNIS factsheet.
Characterising Species or features	List of the species used to characterise the habitat.
Distribution	Where available the distribution data from JNCC is given with a link to the relevant web page (http://jncc.gov.uk/marine/biotopes/biotope.aspx)
Potential legal status of habitats	Legal protection status in Scotland for this habitat type.
Species legal status	Legal protection status in Scotland for any characterising species E.g. any species listed in EU Habitats Directive Annex I, The OSPAR Convention Annex IV or as UKBAP species
Species vulnerability factors	Species vulnerability factors data from the Marlin website was used for this study (http://www.marlin.ac.uk/species.php).

This information was gathered as far as possible for each habitat and species and is presented within Annex II.

4 Identification of Potential Interactions

The objective of this task was to identify where interactions could occur between the technical elements outlined in Section 2 and the habitats and species identified in Section 3.

This task generated the following outputs:

- an assessment demonstrating the ability of technologies, moorings and support structures to exert each environmental pressure;
- an assessment of the vulnerability of all relevant species and habitats to each environmental pressure;
- a table showing which moorings and support structures are likely to be installed with each technology type; and
- the electronic tool then produced a table containing all potential interactions between the technologies, moorings and support structures and the relevant species and habitats.

During the 2014 review, all results and outputs from the initial study were reviewed by the study team:

- **an assessment demonstrating the ability of technologies, moorings and support structures to exert each environmental pressure – reviewed by Aquatera**
- **an assessment of the vulnerability of all relevant species and habitats to each environmental pressure:**
    - **Benthic habitats and species – ERI**
    - **Fish – ICIT**
    - **Marine birds – Aquatera**
    - **Marine mammals – SMRU Marine Ltd**

During the initial study, around 29,329 potential interactions were identified. During the review, 72,477 were identified. Note this increase was due to the inclusion of additional technologies/moorings in the assessment.

Having collated available information on the technical components, species and habitats, the team then used this information in a series of assessments that together would identify significant interactions between the proposed wave and tidal energy developments and the 'sensitive species and habitats' within Scotland's marine environment.

In order to identify a list of key issues associated with marine energy development, it was first necessary to identify *all* potential interactions between the various wave and tidal energy converters, associated moorings and support structures and the selected habitats and species. One of the key project drivers for this process was to be comprehensive and transparent so that any tools developed could be reapplied when new and better information regarding interactions, species, habitats and wave and tidal energy converters becomes available.

These assessments to identify all the potential interactions between the proposed wave and tidal energy developments and sensitive species and habitats are shown in white in Figure 4.1 and are described in more detail in the following sections.

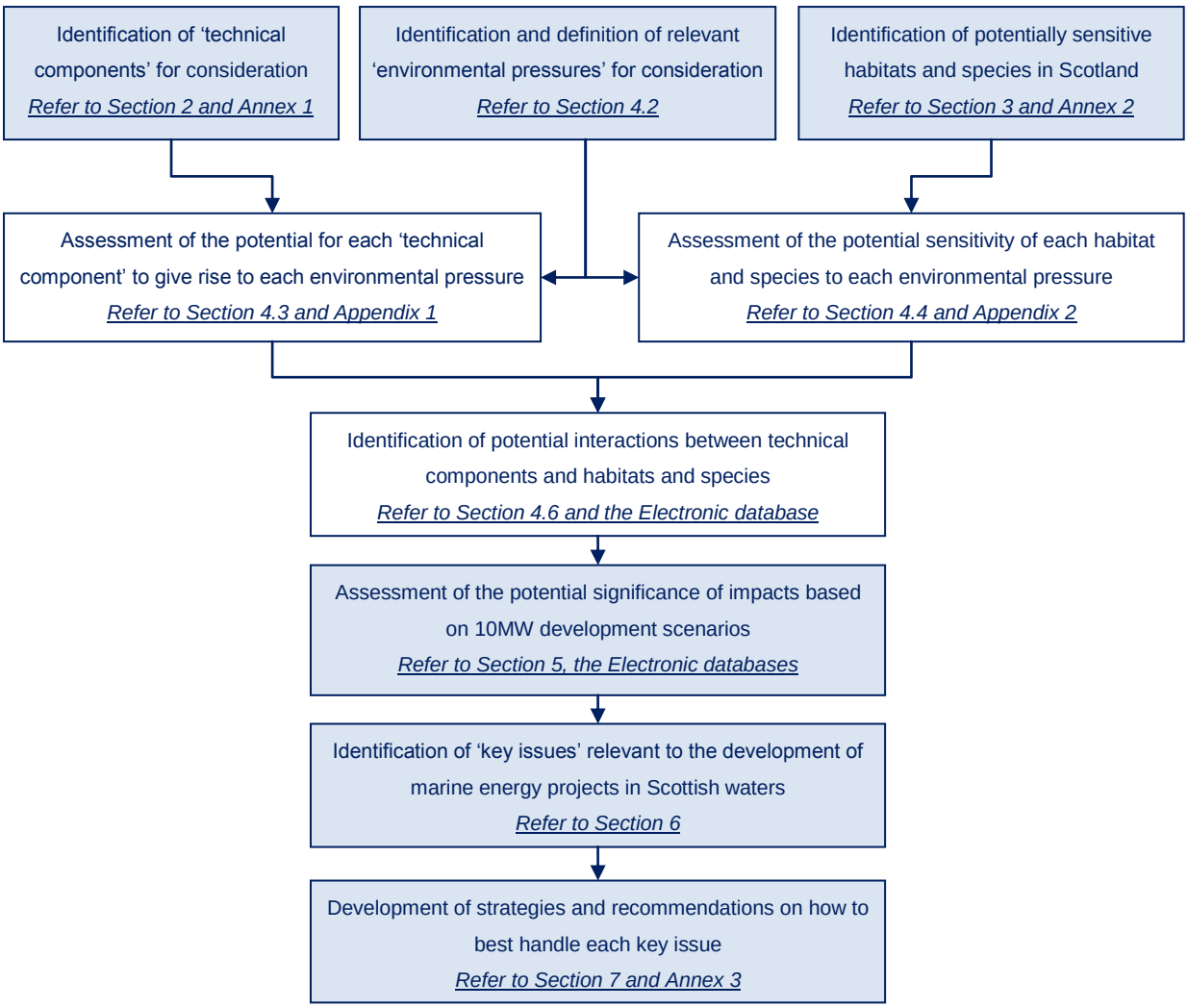

Figure 4.1 Identification of all interactions

4.2 Identification and definition of relevant environmental pressures

The first task within the assessment process was to identify a relevant set of 'environmental pressures' against which the sensitivity of species and habitats could be assessed. The ability of the technical elements to give rise to each environmental pressure was also assessed. The following list of environmental pressures and their definitions was agreed upon by the Project Team (refer to Table 4.1).

Table 4.1 Environmental pressures[6]

Environmental pressure	Definition
Direct abrasion	Direct abrasion of the seabed from structures and equipment e.g. chains, wires, ropes
Direct vibration	Transmission of vibration into the seabed from moving structures and power generation equipment
Scour	Movement of sediments due to accelerated flows and turbulence induced by structures on or near the seabed
Increased/reduced deposition	Change in accumulation/erosion of mobile or suspended sediments and organic matter due to reduced flows or turbulence arising downstream or in the shadow of structures.
Changes in sediment dynamics	Changes to coastal or seabed sediment dynamics due to changed wave action and/or altered tidal currents.
Smothering	The physical covering of the species or community and its substratum
Loss of seabed habitat	Removal/loss of seabed habitat by e.g. placement of structures, excavation, spoil disposal
Dissipation of wave energy	Reduced wave action due to the presence of marine energy devices leading to calmer waters or less exposed coastlines
Change in tidal flows and fluxes	Alteration to the velocity, direction, quantity and or duration of flows due to structures or dynamic processes
Changes in turbidity	Changes in levels of suspended sediment and water column turbidity due to the presence or operation of devices.
Changes in turbulence	Reduced/increased turbulence in the water column from the presence of passive structures or the movement of blades
Change in mixing zone location/structure	Alteration to the location or structure of a mixing zone between stratified and mixed areas due to changes in wave action or current flux
Underwater noise and vibration	Noise generated below the surface during installation/removal activities or device operation
Light below the surface	Artificial sources of light below the surface
Noise above the surface	Noise generated above the surface of the water
Light above the surface	Artificial sources of light above the surface
Visual disturbance	Perception of new objects in the environment that causes a physical or behavioural response that could affect the animal's ability to feed or breed successfully

[6] This list of environmental pressures and the corresponding definitions was reviewed by the project team during the review process.

Environmental pressure	Definition
Displacement of essential activities	Displacement (movement away/repulsion from an area) of activities such as foraging, breeding, moulting, courtship behaviour or loafing due to disturbance (e.g. noise, visual, light)
Loss of shoreline habitat	Removal of shoreline habitat (by excavation, spoil disposal or placement of structures) or physical exclusion from an area due to the presence of structures
Loss of water column habitat	Physical exclusion from an area due to the presence of structures below the surface
Habitat creation	Creation of new habitat from the placement of new structures
Collision risk	Impact with structures at/below the surface leading to injury/mortality
Entrapment	Entrapment within device basins/voids or within device/mooring arrays
Entanglement	Entanglement of marine wildlife leading to injury/mortality
Barrier to movement	Structure causing an obstacle to normal movement of wildlife along important routes e.g. those frequently travelled, between foraging sites and breeding/roosting/haulout sites and routes used for migratory or seasonal passage movements

This list was developed as a starting point based on the best available knowledge and understanding regarding the environmental pressures associated with wave and tidal energy. As with all elements of this study, as new and better information becomes available, the tools created during this project allow for these pressures to be modified, added to and indeed removed where appropriate in future iterations.

4.3 Assessment 1 – potential for technical elements to give rise to environmental pressures

Each of the wave and tidal energy converters and the associated moorings and support structures was assessed individually for its potential to give rise to the environmental pressures listed in Table 4.1 using the definitions given below:

- NA (not applicable) – it is not possible for the technology/moorings/support type to give rise to this environmental pressure;
- Y (yes) – the technology/moorings/support type has the potential to give rise to this environmental pressure at 10MW scale of development;
- N (no) – the technology/moorings/support type does not have the potential to give rise to this environmental pressure at 10MW scale of development; and
- U (unknown) – at this current time, it is unknown whether the technology/moorings/support structure type has the potential to give rise to this environmental pressure.

The full outcome of this process is presented within Appendix 1 and an excerpt in Figure 4.2.

		Tidal technologies				
	Technology, moorings and support structures	Axial-flow turbine	Cross-flow turbine	Reciprocating hydrofoils	Archimedes screw	Tidal Kite
Environmental Pressure						
Direct abrasion		NA	NA	NA	NA	NA
Direct vibration		Y	Y	Y	Y	U
Scour		NA	NA	NA	NA	NA
Increased/reduced deposition		Y	Y	Y	Y	Y
Changes in sediment dynamics		Y	Y	Y	Y	Y
Smothering		NA	NA	NA	NA	NA
Loss of seabed habitat		NA	NA	NA	NA	NA
Dissipation of wave energy		NA	NA	NA	NA	NA
Change in tidal flows and fluxes		Y	Y	Y	Y	Y
Changes in turbidity		N	N	N	N	N
Changes in turbulence		Y	Y	Y	Y	Y
Change in mixing zone location/structure		Y	Y	Y	Y	Y
Underwater noise and Vibration		Y	Y	Y	Y	Y
Light below the surface		U	U	U	U	U
Noise above the surface		NA	NA	NA	NA	NA
Light above the surface		NA	NA	NA	NA	NA
Visual disturbance		Y	Y	Y	Y	Y
Displacement of essential activities		Y	Y	Y	Y	Y
Loss of shoreline habitat		NA	NA	NA	NA	NA
Loss of water column habitat		Y	Y	Y	Y	Y
Habitat creation		Y	Y	Y	Y	Y
Collision risk		Y	Y	Y	Y	Y
Entrapment		N	N	N	N	N
Entanglement		NA	NA	NA	NA	NA
Barrier to movement		Y	Y	Y	Y	Y

Figure 4.2 Excerpt from Appendix 1 – technology types and environmental pressures

Justifications are presented for all results in Appendix 1 (an example is also shown in Figure 4.3). This is intended to ensure transparency and to allow any amendments/updates to be made at the earliest opportunity. Once testing and monitoring of devices progresses, this assessment regarding technology, moorings and support structures can be updated/modified to inform and shape the latter stages of the assessment.

	Technology type	Axial-flow turbine		Oscillating wave surge converter
Environmental Pressure				
Direct abrasion		Not applicable - no components on the seabed (refer to moorings and support structures)		Not applicable - no components on the seabed (refer to moorings and support structures)
Direct vibration		Yes - device positioned directly on the seabed allowing transmission of vibration into/onto the seabed		Yes - device positioned directly on the seabed allowing transmission of vibration into/onto the seabed
Scour		Not applicable - no components on the seabed (refer to moorings and support structures).		Not applicable - no components on or near the seabed
Increased / reduced deposition		Yes - device may create a shadow, reduce flows or change turbulence resulting in the deposition of mobile sediments		Yes - device may create a shadow, reduce flows or change turbulence resulting in the deposition of mobile sediments
Changes in sediment dynamics		Yes - extraction of tidal energy may result in changes to coastal or seabed sediment dynamics due to effects of alterations in tidal flows resulting in the deposition of mobile sediments		Yes - extraction of wave energy may result in changes to coastal or seabed sediment dynamics due to effects of wave energy dissipation resulting in the deposition of mobile sediments

Figure 4.3 Excerpt from Appendix 1 – technology types and environmental pressures

4.4 Assessment 2 – sensitivity of habitats and species to environmental pressures

All habitats and species were assessed for potential sensitivity to each environmental pressure using the information collated into the habitats and species guides (refer to Section 3 and Annex 2). The following definitions were used in this assessment:

- D (direct) – the species/habitat has the potential to be directly affected by the environmental pressure;
- I (indirect) – the species would be indirectly affected by the environmental pressure (e.g. the environmental pressure may directly affect prey species, prey availability etc.);
- N (not sensitive) – the environmental pressure would not affect this species/habitat; and
- U (unknown) – at this time there is no information available to determine if this species/habitat would or would not be affected by the environmental pressure.

Note: at this stage, the assessment focused solely on the sensitivity of species/habitats to the specific environmental pressure without considering potential causes; i.e. no consideration was given to technology types, moorings etc. The decision was taken to adopt this approach largely due to the lack of understanding and evidence regarding the effects of marine energy development on the marine ecological environment. For instance, whilst it is difficult to comment on the level of impact of a technology on a particular species or habitat, it is possible to comment (in most cases) on the likelihood of a technology exerting a particular environmental pressure that a species or habitat may be sensitive to. It is also possible (again in most cases) to comment on the potential sensitivity of a species or habitat to a particular environmental pressure. Therefore, by developing a set of environmental pressures and essentially *linking* technology types etc. to species and habitats in this way, it is possible to conduct an effective and accurate high level impact assessment. A shorter list of environmental pressures was assessed against the benthic species and habitats as it was decided that some of the environmental pressures (e.g. collision) were not relevant to benthic habitats and species.

An excerpt of the outcome of this process in presented in Figure 4.4 and in full within Appendix 2.

Species	Spiny Dogfish	Small-spotted Catshark	Basking Shark	Porbeagle Shark	Tope Shark	Cuckoo Ray	Spotted Ray	Thornback Ray	Common Skate	Atlantic Herring	Sprat	Atlantic Salmon	Sea Trout	
Environmental Pressure														
Direct abrasion	I	D	N	I	I	D	D	D	D	D	N	I	I	
Direct vibration	U	U	N	U	U	U	U	U	U	U	N	U	U	
Scour	I	I	N	I	I	D	D	D	D	D	N	I	I	
Increased/reduced deposition	I	I	N	I	I	D	D	D	D	D	N	I	I	
Changes in sediment dynamics	I	I	N	I	I	D	D	D	D	D	N	I	I	
Smothering	I	D	N	I	I	D	D	D	D	D	N	I	I	
Loss of seabed habitat	D	D	N	D	D	D	D	D	D	D	N	D	D	
Dissipation of wave energy	I	I	I	I	I	N	N	N	I	I	I	I	I	
Change in tidal flows and fluxes	I	I	I	I	I	N	N	N	I	D	D	N	N	
Changes in turbidity	D	D	I	D	D	D	D	D	D	D	D	D	D	
Changes in turbulence	I	I	I	I	I	N	N	N	I	D	D	N	N	

Change in mixing zone location/structure		D	D	D	D	D	D	D	D	D	D	D	D	D	
Underwater noise and Vibration		D	D	D	D	D	D	D	D	D	D	D	D	D	

Figure 4.4 Excerpt from Appendix 2 – habitats and species and environmental pressures

Justifications are presented for all results in Appendix 2. This is intended to ensure transparency and to allow any amendments/updates to be made at the earliest opportunity.

Each scoring category was handled accordingly:

- D (directly sensitive) – species/habitat directly sensitive to environmental pressure therefore taken forward and assessed against all technical elements capable of exerting that particular environmental pressure;
- I (indirectly sensitive) – species/habitat indirectly sensitive to environmental pressure. Justifications given (refer to Appendix 2) but not considered further as indirect effects were not the main focus of this study and the vast majority related to prey species, which would be covered in other parts of the initial assessment. For example, indirect effects within the bird sensitivity assessment relating to effects on bird prey species, if significant, would be caught as direct effects within the fish and shellfish sensitivity assessment;
- N (not sensitive) – species/habitat not sensitive to environmental pressure; justifications provided (refer to Appendix 2) but not considered further; and
- U (unknown) – unknown whether the species/habitat is sensitive to environmental pressure and therefore taken forward and considered further in the assessment.

4.5 Compatibility of wave and tidal energy converters with moorings and support structures

As an interim step, it was necessary to identify which technology types would be installed using which moorings/support structures. The following table shows all possible combinations of wave and tidal energy converters and moorings/support structures. Each combination has been assessed as follows:

- Y (yes) - combinations that are currently being considered by technology developers;
- N (no) – combinations that are not currently being considered by technology developers but are technically possible; and
- NA (not applicable) – combinations that are not technically possible.

By completing this process, it was possible within the assessment to focus on likely development scenarios and to avoid the need to assess potential impacts that will most likely never arise, for example, from an installation involving a horizontal axis turbine and embedment anchors. Only known combinations (i.e. scoring ‘yes’ in Table 4.2) were considered during in the assessment process against the habitats and species found to be sensitive to each environmental pressure.

These first three tasks within the core assessment process resulted in the following information outputs:

- technology types/moorings/support structures that would potentially give rise to certain environmental pressures;
- species/habitats that would potentially be sensitive to certain environmental pressures; and
- technology types likely to be deployed using moorings/support structure type.

Table 4.2 Compatibility of devices and moorings/support structures for tidal devices

	Gravity base structure	Driven/percussion piles	Drilled and Grouted piles	Rock anchors /Pinned gravity base	Gravity anchor and mooring lines	Rock anchors and mooring lines	Embedment anchor and mooring lines	Gravity anchor, mooring lines and floating pontoon	Rock anchors, mooring lines and floating pontoon	Gravity anchor and taut mooring lines	Rock anchors and taut mooring lines
Axial-flow turbine	Y	Y	Y	Y	NA	NA	NA	Y	Y	Y	Y
Cross-flow turbine	Y	Y	Y	Y	NA	NA	NA	Y	Y	N	N
Reciprocating hydrofoils	Y	Y	Y	Y	NA	NA	NA	N	N	N	N
Archimedes screw	Y	Y	Y	Y	NA	NA	NA	N	N	N	N
Tidal Kite	NA	NA	NA	NA	NA	NA	NA	N	N	Y	Y

Table 4.3 Compatibility of devices and moorings for wave devices

	Gravity base structure	Driven/percussion piles	Drilled and Grouted piles	Rock anchors /Pinned gravity base	Gravity anchor and mooring lines	Rock anchors and mooring lines	Embedment anchor and mooring lines
Oscillating wave surge converter	Y	Y	Y	Y	NA	NA	NA
Submerged pressure differential	Y	N	N	Y	NA	NA	NA
Oscillating water column (offshore)	N	N	N	N	Y	Y	Y
Overtopping device (offshore)	N	N	N	N	Y	Y	Y
Attenuator	N	N	N	N	Y	Y	Y
Rotating mass	NA	NA	NA	NA	Y	Y	Y
Point absorber	NA	NA	NA	NA	Y	Y	Y

4.6 Electronic tool

For an interaction to occur between a species/habitat and a technology/mooring/support structure combination, the species/habitat must be sensitive to an environmental pressure that the technology etc. is likely to cause. This process is summarised in Figure 4.5:

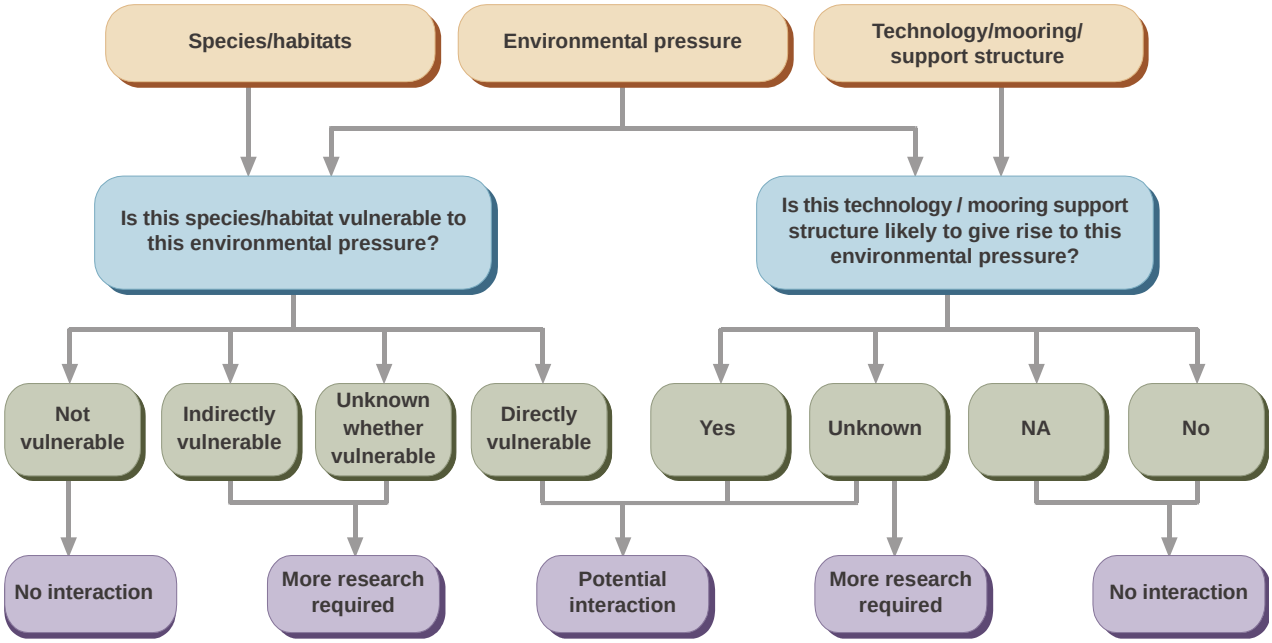

Figure 4.5 Identification of potential interactions

To conduct the initial impact assessment process, Aquatera developed an electronic tool that essentially completed the tasks summarised in Figure 4.5 and built-up a database of all potential interactions between habitats and species and technical elements.

5 Assessment of Potential Significance of Identified Interactions

The objective of this task was to assess the potential significance of the interactions identified during the initial steps of the assessment process and to identify a set of potential key issues that may arise from the development of wave and tidal energy.

This task generated the following outputs:

- a set of criteria for scoring potential interactions at a 10MW scale of development was produced;
- **all** potential interactions were assessed using the criteria developed and justifications were produced for **all** scores given; and
- a set of potential key interactions was produced based on the outcome of the assessment process.

During the 2014 review, all assessment results and justifications produced during the initial study were reviewed and revised by the project team as necessary based on recent research and improved understanding. Additionally, all potential interactions associated with the new technologies included during the review process were fully assessed by the team and justifications provided throughout.

The project database (IMPACT) was also fully updated based on the revised and new assessment results and justifications.

Having identified all the potential interactions (a total of 72,477 potential interactions), it was then necessary to conduct a high level assessment of potential significance so as to determine which interactions pose a potentially significant threat to the associated habitats and species. Given the lack of knowledge regarding a number of the species and habitats, technology types and moorings and the likelihood and consequence of any potential interactions, a number of boundaries were defined to allow the Project Team to make informed judgements based on existing information and a number of balanced assumptions. To this end, it was decided that the assessment would be completed for 10 megawatt installations only, i.e. 10MW of installed capacity of each technology type and the appropriate number of associated moorings. Therefore, each Project Team member was asked to assess each potential interaction identified during the previous stage of the assessment process based on the information provided within the technology guides, with particular reference to information regarding the character of a 10MW development of each technology type. The Project Team was **not** asked to consider the potential effects of associated support vessel activity, infrastructure development etc., only those technical elements outlined in Section 2.

In order to allow the assessors to essentially 'score' the potential significance of an interaction based on the assumption of a 10MW array with the necessary supporting moorings and structures in place, a set of criteria had to be developed. This posed a particular problem given the lack of data and evidence regarding the majority of the potential interactions. Therefore, the criteria had to be flexible and yet structured enough to allow the Project Team assessors to apply an approach that involved

identifying 'reasonable hypotheses'[7] for interactions and to then make judgements using the best available information and subjective expert opinion regarding the potential significance of the effect at a 10MW scale. To this end, the criteria in Table 5.1 were developed among the team.

Separate criteria were developed for benthic habitats and species, marine mammals, marine birds, and fish and shellfish. This allowed the criteria to be tailored specifically to each category making the assessment process more transparent and effective.

[7] A 'reasonable hypothesis' should be based on logic or existing evidence. Where a reasonable hypothesis cannot be made, it should be considered whether the interaction has the potential to be significant should it occur.

Table 5.1 Scoring criteria for assessing significance of interactions

Score	Marine birds	Marine mammals	Fish and shellfish	Benthic habitats and species
1	There is a reasonable hypothesis that the potential exists to cause death/injury or to affect behaviour in a way that has negative consequences for energy intake that could lead to a change in the stability of the regional population or within an SPA population	There is a reasonable hypothesis that: • the development of a 10MW array may potentially lead to the death/severe injury of an individual cetacean; or • the development of a 10MW array may lead to the death/injury/disturbance of a significant number of seals/otters to the extent that would result in a change in stability of the local/regional population or an SAC population.	There is a reasonable hypothesis that a 10MW array would result in a change in the stability of the Scottish population bearing in mind that some species may already be under pressure due to other factors (e.g. climate change, fisheries pressures)	There is a reasonable hypothesis that the impact from a 10 MW array will cause: • the habitat to be fully or partially destroyed; or • major and larger-scale (beyond the seabed footprint of the array) effects on the survival or viability of species that characterise the habitat, that provide key structure or function for the habitat or that are of natural heritage importance in that habitat (i.e. those in Biodiversity Action Plans).
0	There is a reasonable hypothesis that a 10MW array will not result in a change in the stability of the regional population or within an SPA population	There is a reasonable hypothesis that: • the development of a 10MW array will not lead to the death/severe injury of an individual cetacean; or • the installation of a 10MW array will not lead to the death/injury/disturbance of a significant number of seals/otters to the extent that would result in a change in stability of the local/regional population or an SAC population.	There is a reasonable hypothesis that a 10MW array would not result in a change in the stability of the Scottish population bearing in mind that some species may already be under pressure due to other factors (e.g. climate change, fisheries pressures)	There is a reasonable hypothesis that the impact from a 10 MW array has, at most, only minor and local effects (within the actual seabed footprint of the array) on the survival or viability of species that characterize the habitat, that provide key structure or function for the habitat or that are of natural heritage importance in that habitat (i.e. those in Biodiversity Action Plans)
NA	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Score	Marine birds	Marine mammals	Fish and shellfish	Benthic habitats and species
Unknown	It is unknown at this time: • whether an interaction between the species and technology/mooring /support structure is possible/likely to occur; or • if the effect on the species concerned is likely to result in a change in stability of the local/regional population	It is unknown at this time: • whether an interaction between the species and technology/mooring system/support structure is possible/likely to occur; • if the effect of a particular environmental pressure or a combination of pressures on the species concerned is likely to result in a change in stability of the local/regional population; or • whether the removal of a single individual from a population is significant and likely to result in a change in stability of the local/regional population.	It is unknown at this time: whether a 10MW array would or would not result in a change in the stability of the Scottish population bearing in mind that some species may already be under pressure due to other factors (e.g. climate change, fisheries pressures)	Category not used for benthic habitats/species

Using these criteria, all potential interactions were assessed by members within the team:

- marine birds – Aquatera;
- marine mammals– SMRU Marine Ltd;
- marine fish and shellfish – ICIT; and
- benthic habitats and species – ERI.

The assessment process was completed using the best available information and should be viewed as an information platform from which to build in the future as new and better information becomes available from testing and monitoring studies around test installations and demonstration arrays. Many of the outcomes are based on the subjective expert opinion of the particular assessor involved. Each judgement has been peer reviewed by at least one other member company/organisation within the Project Team.

From the total number of interactions identified (72,477), 2,833 were scored "1" and a further 9,475 were scored as "unknown". These interactions were taken forward as to the next stage of the assessment. The remaining interactions were score NA (6,903) or Zero (53,266).

Each row in the database deals with a single potential interaction. The example shown in Figure 5.2 shows the following:

Database heading	**Database entry**
Environmental pressure	Collision risk
Device type	Axial-flow turbine
Wave / Tidal	Tidal
Device versus Environmental pressure justification	Yes - static and moving structures placed within the water column
Moorings / support structure type	Drilled and Grouted piles
Moorings / support structure justification	Yes - static structures placed within the water column
Common Name (or habitat considered in Benthic assessment)	Common seal
Score (1, 0, NA, Unknown)	unknown
Comment	It is unknown whether an interaction between seals and tidal turbines is possible / likely to occur. There is potential for collision with moving structures e.g. turbine blades. Collisions with stationary structures e.g. mooring lines / support structures are less likely to cause death but injuries may result. The significance of the impact on seal populations is unknown and will be site-specific. It is unknown whether collision could lead to death / injury of a significant number of seals to the extent that would result in a change in the stability of the local / regional population.
Key issues	Potential for collision between marine mammals and tidal energy converters and associated moorings / support structures

Figure 5.2 Excerpt from electronic database

The full outcome of this assessment process is presented within the electronic database. This information, including scores, comments etc. can be found for all interactions identified.
As shown, a justification was provided for each individual 'score'. This serves two purposes:

- provides complete transparency to the scoring process by clearly stating why the assessor has given a particular score to an interaction; and
- allows any updates in data/information to be fed directly into the process as and when it becomes available. As stated previously, given the current status of understanding, it is important that this is viewed as a tool into which information can be fed to improve the outputs as knowledge and understanding grows.

The interactions were handled in a particular way throughout the remainder of the study depending on the score given by the assessor:

- 1 – a potential effect considered to be potentially significant within the context of a 10MW installation;
- Unknown – the likelihood/consequence of these potential effects is unknown. There is also a lack of supporting evidence or substantial gaps in information regarding the species/habitat/technology/moorings;
- 0 – a potential effect considered likely to be insignificant within the context of a 10MW installation. These potential interactions were not considered further but should be reassessed in the future when further relevant information is available and within the context of larger installations with which the effect may become significant; and
- Not applicable – unlikely to ever occur due to unsuitability of habitat type for development/geographical barriers etc.

Justifications can be found in the electronic database.

Those 'key interactions' scored as either "1" or "unknown" (12,308 interactions in total) are further discussed in Section 6 and strategies for addressing each were developed as discussed in Section 7.

6 Identification of Key Issues

The objective of this task was to develop a set of key issues regarding the potential impacts of wave and tidal energy development on the marine ecological environment so as to help provide focus for project specific and strategic environmental impact assessments and associated research programmes.

This task generated the following outputs:

- A set of key issues relating to Scotland's marine environment that may arise from the development of marine energy was produced.

During the 2014 review, the list of key issues was revised based on the updated impact assessment results. During the initial study, 19 key issues were identified. During the 2014, 22 key issues were identified.

From the assessment process, a list of 12,308 potentially significant interactions was identified, those having scored as potentially significant (those that were scored '1') within the context of a 10MW development along with those for which the potential significance could not be assessed due to an essential gap in data/information (those that were scored 'unknown'). All potentially significant interactions were grouped into themes or key issues[8]. A record of the key issue into which each interaction was grouped is shown within the electronic database.

This task essentially ended the assessment process of the study, resulting in a list of key issues relating to the potential effects of marine energy development on Scotland's marine environment.

All identified key issues are listed in Table 6.1 along with the relevant environmental pressures that were considered during the assessment process. A number of the key issues deal with multiple environmental pressures.

[8] Note that percussion / driven piling has been removed from the list of key issues as it is not thought that this method would be used in environments suitable for wave and tidal devices.

Table 6.1 Key issues and corresponding environmental pressures[9]

Ref	Key issue	Relevant environmental pressure(s)
Marine mammals		
1	The potential effects on marine mammals from underwater noise generated by operational wave and tidal energy converters	Underwater noise and vibration
2	The potential effects on marine mammals from underwater and above surface noise generated during piling and drilling activities	Underwater noise and vibration, Noise above the surface
3	Potential for collision between marine mammals and tidal energy converters and associated moorings / support structures	Collision risk
4	Potential for collision between marine mammals and offshore wave energy converters and associated moorings / support structures	Collision risk
5	Potential barrier to movement for marine mammals due to the presence of wave and tidal energy converters and associated moorings / support structures	Barrier to movement
6	It is unknown whether the potential exists for cetaceans to become entangled in mooring lines	Entanglement
7	Potential risk of entrapment of marine mammals within device chambers and mooring arrays	Entrapment
8	Direct loss of habitat for seals and otters due to the installation of shoreline wave energy converters	Loss of shoreline habitat
9	Potential displacement of essential activities of marine mammals due to the presence of wave and tidal energy converters and associated moorings / support structures	Displacement of essential activities
Basking sharks		
10	Potential for collision between basking sharks and tidal energy converters and associated moorings / support structures	Collision risk
11	Potential displacement of essential activities of basking sharks due to the presence of tidal energy converters and associated moorings / support structures	Displacement of essential activities
12	It is unknown whether the potential exists for basking sharks to become entangled in mooring lines	Entanglement
13	Potential risk of entrapment of basking sharks from mooring arrays	Entrapment
Marine Birds		
14	Potential displacement of essential activities of marine birds due to the physical and visual presence of wave and tidal energy converters and associated moorings / support structures	Displacement of essential activities Visual disturbance
15	The potential effects on diving birds from underwater noise and vibration generated during driven / percussion piling activities	Underwater noise and vibration
16	Potential for collision between diving birds and tidal energy converters and associated moorings / support structures	Collision risk

[9] Please note that these are listed and referenced in no particular order

Ref	Key issue	Relevant environmental pressure(s)
17	Direct loss of breeding habitat for marine bird species due to the installation of shoreline wave energy converters	Loss of shoreline habitat
18	Potential effects of changes in turbulence on foraging success of diving birds due to the presence of wave and tidal energy converters and associated moorings / support structures	Changes in turbulence
Benthic habitats/species		
19	Direct loss of protected or sensitive sub-littoral seabed communities due to the presence of wave and tidal energy converters and associated moorings or support structures on the seabed	Loss of seabed habitat Direct abrasion
20	The potential wider or secondary effects on protected or sensitive sub-littoral seabed due to installation and operation of wave and tidal energy converters and associated moorings or support structures	Scour Increased/reduced deposition Changes in sediment dynamics Smothering Change in tidal flows and fluxes Dissipation of wave energy
21	Direct loss of protected or sensitive littoral coastal communities due to the placement of shoreline or nearshore wave energy converters	Loss of shoreline habitat
22	The potential wider or secondary effects on protected or sensitive littoral coastal communities due to installation and/or operation of wave and tidal energy converters and associated moorings or support structures	Scour Increased/reduced deposition Changes in sediment dynamics Smothering Dissipation of wave energy

7 Developing Strategies for Handling Key Issues

The objective of this task, outwith the assessment process, was to develop outline strategies and suggested measures for addressing each key issue on a project specific basis which could then be used to facilitate discussions between project developers and key stakeholders during a project specific EIA. This information is **not** prescriptive and should be viewed as a starting point for discussion.

This task generated the following outputs:

- A set of strategies for addressing the key issues associated with the development of marine energy in Scotland was produced.

During the 2014 review, the strategies developed during the initial study were reviewed and updated, producing a comprehensive report (Annex 3) containing; an overview of the key issues, the relevant assessment results and a strategy for addressing each key issue at a project level for single device deployments and demonstration scale arrays. During the review process, suggested strategic research measures that could be implemented to help address each key issue were also developed.

As stated previously, the main objectives of this study were to identify and prioritise the potential key issues associated with the development of marine energy and Scotland's marine ecological environment and to develop suitable strategies that can be used by developers, regulators and advisors to inform project specific EIAs, baseline surveys and monitoring plans on a project-specific and site-specific basis.

A strategy for addressing each key issue based on the current status of the industry, best available knowledge regarding technology development pathways, regulatory concerns and the key environmental issues flagged up during the assessment process was developed (see Annex 3). These strategies provide a series of suggested activities and recommendations that may be undertaken to address each key issue. This information is not prescriptive and should be used as a platform for discussion on a project and site specific basis in order to develop an appropriate impact assessment strategy and monitoring programme for the project.

In Appendix3, commentary and recommendations regarding the following are provided for each key issue in relation to a single device deployment and a demonstration array:

- Desk based studies
- Baseline characterisation surveys
- Further desk based studies
- Monitoring during and post deployment
- Supplementary research opportunities

Objectives and recommendations are provided with regards to each suggested measure/activity.

The following information is also provided for each key issue:

- The relevant technologies and support structures
- List of species / groups that may be vulnerable
- Summary of possible effects and potential significance

This appendix is split into the following sections:

- marine mammals;
- basking shark;
- marine birds; and
- benthic species and habitats.

8 Conclusions

As shown in this report and the set of extensive appendices and annexes, there is a wide range of potential interactions between wave and tidal energy developments and the marine ecological environment, but the majority of potential interactions may potentially be of little concern at the demonstration array scale. There remain, however, a number of specific key issues that have the potential to significantly affect marine habitats and species that need to be addressed on a site and project specific level by developers and stakeholders. These issues (in no particular order) are listed earlier in Table 6.1.

It was not appropriate to address each of these issues in specific detail in a project such as this, particularly since the site and project specific context will play an important role in establishing the most appropriate strategy. It is possible, however, to make a series of recommendations as to how these issues could be addressed during project specific EIAs (for single deployments and for demonstration arrays) based on the information fed into the assessment process and the judgements made by the Project Team.

It is hoped that the series of 'strategies' developed for each issue (refer to Annex 3) issue can be used to facilitate discussions between project developers, regulators, advisors and other stakeholders during the initial stages of a project specific EIA, i.e. during pre-scoping consultation. These strategies should be used as a starting point for discussion and should be developed further taking into account the site-specific environmental baseline conditions and the technical character of the project.

It should be noted that the guidance and recommendations provided developed during this study are aimed at developers and regulators considering particular projects or sites and are designed to help define project and site specific environmental assessments and monitoring plans. It is important to note that a number of key issues identified during the assessment process would be best addressed through a coordinated strategic research programme involving developers, regulators, stakeholders and the research community.

It is essential that developers are able to develop and implement proportionate and site specific approaches to site assessments, environmental impact assessments, mitigation and monitoring plans. However, it is also critical at this stage of the industry's development that targeted and coordinated strategic environmental research is undertaken in parallel with the first device deployments and demonstration array developments so as to reduce uncertainly around potential key issues that may become more relevant when considering future large scale wave and tidal energy projects. This will help ensure that information and understanding needed to inform commercial scale environmental assessments and consenting processes is available when it is required.