THE CROWN ESTATE

Pentland Firth and Orkney Waters

Enabling Actions Report

PFOW wave and tidal stream projects and migratory salmonids

July 2013

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- Toby Gethin, The Crown Estate
- The project Review Group
- All delegates at the workshop

Bibliographic Policy

The Client has agreed that references in this document may be cited as web links as appropriate.

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This report has been published by The Crown Estate as part of its Enabling Actions work to support development of the Pentland Firth and Orkney waters (PFOW) wave and tidal projects. This work aims to accelerate and de-risk the development process, looking at a range of key issues. Work is selected, commissioned and steered by The Crown Estate in close discussion with the PFOW project developers.

For more information on The Crown Estate's work in wave and tidal energy, see www.thecrownestate.co.uk/energy/wave-and-tidal/ or contact waveandtidal@thecrownestate.co.uk.

The Crown Estate's Wave and Tidal programme hosted a workshop, in Thurso, on 17th and 18th April 2013, to bring together and facilitate discussion between relevant key stakeholders concerned with wave and tidal developments in the PFOW area and their potential impacts on migratory salmonids.

The Crown Estate commissioned Epsilon Resource Management Ltd to prepare a Review and Discussion Paper to help advise the workshop, to organize and deliver the workshop, and to prepare this final report which is divided into four main sections:

Epsilon Resource Management Limited

BIDWELLS

PFOW wave and tidal stream projects and migratory salmonids

Pentland Firth and Orkney Waters

Enabling Actions Report

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CONTENTS

EXECUTIVE SUMMARY

Epsilon Resource Management was commissioned by The Crown Estate to organise and deliver a workshop on the potential impacts of wave and tidal energy stream developments on migratory salmonids in the PFOW area. The workshop was held in Thurso on the 17th and 18th of April 2013. A Review and Discussion paper (DP) was initially prepared by Epsilon Resource Management, based on literature searches and face to face consultation with developers and key stakeholders and guided by a Review Group appointed by The Crown Estate. The DP was provided to delegates in advance of the workshop, and served to structure the group discussions that comprised the bulk of the workshop.

The overall aim of the Project was to deliver written detail on:

- The potential impacts from wave and tidal stream developments on migratory fish, taking into account cumulative impacts and considering mitigation measures that might be applicable and practical
- The current state of knowledge and 'knowledge gaps' as to the potential of any of the possible impacts actually having a quantifiable negative effect within the PFOW area
- The agreed/recommended approach as to how the industry could address the identified key issues/knowledge gaps related to the actual key potential impacts on migratory fish from the PFOW projects.

This report includes the DP (updated since the workshop) and summarises the outcomes from the workshop, identifies **key points**, and makes several specific **recommendations** with respect to de-risking the development process. It is recognised that not everyone will agree with all the recommendations, but each of them is based on either a consensus or an overwhelming majority view from the workshop in Thurso.

It is important to carefully read all sections of this report, and particularly the DP summary in Chapter 6 and the workshop summary in Chapter 8.

Key Points:

1. 17 Scottish rivers are designated as Special Areas of Conservation (SAC) for Atlantic salmon and / or freshwater pearl mussels, and it is the migratory behaviour of Atlantic salmon that potentially causes the concerns that prompted The Crown Estate to organise the Thurso workshop

2. There is already a good body of knowledge, globally, about possible interactions between wave and tidal stream devices and migratory salmonids (Chapter 4), but there are still some knowledge gaps, and research is underway in order to fill these gaps (Chapter 5)
3. Of the types of interactions that could occur between wave and tidal energy devices and migratory salmonids, **collision**, **noise** and **electro-magnetic fields** (**EMF**) are generally considered to be the most important
4. It was agreed at the workshop that different types of development (whether wave or tidal, or different types of equipment in either category), in different locations, posed different degrees of risk to migratory salmonids, and thus the 'case by case' principle to all aspects of consenting was firmly established
5. There was some recognition that **collision** was probably the greater risk for some tidal energy stream devices, but the workshop largely concluded that ongoing research into potential noise and EMF interactions is also important
6. Following from that, it was agreed that there were **two** main themes for future research and for modelling exercises to consider:
    a. Whether there would be migratory salmonids sufficiently physically co-incident with proposed wave and / or tidal sites for there to be a measurable effect on the fish. This issue was expanded to
        i. Recognise that 'physically co-incident' did not necessarily mean physically touching the equipment – effects of noise, EMF and even water turbulence may be important
        ii. Take account of temporal variations in presence or absence, i.e. seasonally migrating fish
        iii. Also take account of the importance of the genetically distinct seasonal stock components
        iv. Take account of the numbers of individuals involved
        v. Take account of other behavioural characteristics such as depth in the water column – i.e. a three dimensional component
    b. Whether, even if there were to be some physical co-incidence, there was actually a mechanism for an impact to occur
7. Presentations were made to the workshop in relation to the types of research and modelling that are currently being undertaken or developed, and these were broadly welcomed. Difficulties associated with the application of some techniques, such as tagging, in the high energy waters of the PFOW area were acknowledged

8. There was a strong plea for more collaboration on designing, funding and implementing research, and a wave and tidal energy equivalent of the Offshore Renewables Joint Industry Programmes (ORJIP) initiative was mentioned
9. The Marine Scotland Licensing Operations Team (MSLOT) approach to consenting was discussed at the workshop, in conjunction with the fact that early projects would deploy small numbers of commercial scale devices. This led to a broad discussion about the nature of the 'monitoring' that would be appropriate in order to ascertain whether the devices were having any impact on migratory salmonids – with a clear need to distinguish between monitoring that developers might be asked to implement, and other research / monitoring that should be in the purview of a wider set of industries and/or the public sector bodies
10. Having established the case by case approach to the consenting process, the workshop considered the degree / scope of information that developers should try to provide in Environmental Statements and similar documents.
11. It was agreed that in addition to general site information and as much detail as possible (subject to new developments) about the proposed equipment and its emissions / interaction-capabilities, developers should attempt to provide as much baseline information about migratory salmonids in the area as they could reasonably find from existing data sources. Evidencing, as far as possible, an understanding of 'pathways for possible impacts' was also considered important
12. It was also agreed that it was unreasonable to ask developers to attempt to gather new information about migratory salmonids in the area through field or other primary research
13. Modelling, both particle tracking and collision and / or encounter modelling, was discussed in some detail at the workshop. It was agreed that modelling is a worthwhile approach, but that more data are required in order to increase the accuracy of assumptions made during the modelling process
14. Improving communications and ensuring the important information is disseminated and taken on board by stakeholders was a consistent theme throughout the workshop, and several examples where improvements might be made were discussed

Recommendations:

1. MSLOT should continue with the consenting approach it has been following
2. Marine Scotland and others should agree a high-level 'monitoring approach' in order to provide developers with greater clarity as to the likely approach to and funding of any monitoring

required at their projects and will provide stakeholders with a better understanding as to how existing uncertainties will be investigated further

3. The Crown Estate, Marine Scotland and others should explore the establishment of a wave and tidal equivalent of ORJIP to enable a coordinated approach to be progressed, focused on the key research priorities (including but not exclusively migratory salmonids) for the wave and tidal stream sectors
4. Marine Scotland Science (MSS) and others should continue to develop and implement research that helps to establish the behaviour and location of migratory salmonids in the PFOW area
5. The parallel research into mechanisms for interaction and impact should proceed as swiftly as possible
6. The use of modelling techniques by developers, their advisers and others, should be encouraged, as should their refinement as more data become available
7. Scoping advice to developers should be clarified, by MSLOT, and offered on a case by case basis
8. All parties should collaborate more fully on a range of issues, particularly including sharing information and ensuring latest understanding and knowledge is widely disseminated. This will assist with clarifying existing priorities and uncertainties and ensure that aspects which are increasingly well researched and/or understood are acknowledged and the relevant information fully utilised.

SECTION A. REVIEW AND DISCUSSION PAPER

1 INTRODUCTION

1.1 The Project

This Review and Discussion Paper (DP) has been produced by The Crown Estate as part of its Enabling Actions Programme to support the development of the PFOW wave and tidal projects. Its purpose is to assist with structured discussions at the workshop held in Thurso on 17th and 18th April 2013.

1.2 Background

The proposed development of up to 1,600 MW of commercial wave and tidal energy generation capacity in the PFOW area, plus the 30MW Lashy Sound project and the European Marine Energy Centre (EMEC) sites, has been well documented in previous publications[4]. The individual sites with Agreements for Lease (AfL) made by The Crown Estate are discussed further in Chapter 2.

The companies that are taking forward the eleven commercial projects and the one commercial demonstration project (hereafter referred to as 'the developers') require regulatory permission to proceed, specifically a Marine Licence and a Section 36 Consent, both issued by Marine Scotland[5]. A Guidance Manual for the licensing process was issued by Marine Scotland in October 2012[6]. The Manual clearly sets out all the key legislative provisions that must be considered, and in the interest of brevity these will largely not be repeated in this report. It also provides a helpful diagrammatic representation of the steps in the licensing process: Figure 1.

At the time of writing (March 2013), four of the proposed projects are at the pre-scoping stage, seven have submitted EIA Scoping requests, and for one project (MeyGen Ltd), a full Environmental Statement (ES) has been produced and published[7].

[4] [4] See for example: http://www.thecrownestate.co.uk/media/71431/pentland_firth_how_the_projects_could_be_built.pdf
[5] http://www.scotland.gov.uk/Topics/marine/Licensing/marine
[6] http://www.scotland.gov.uk/Resource/0040/00405806.pdf
[7]http://www.meygen.com/the-company/reports-and-documents/

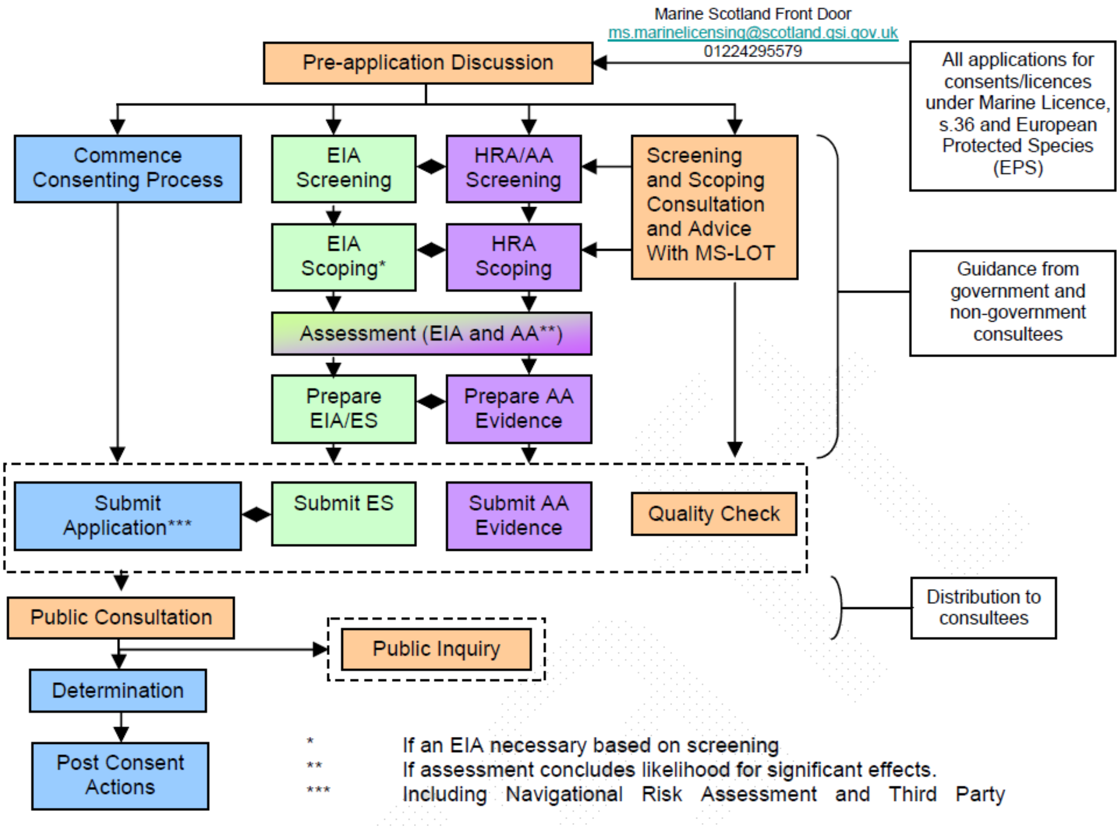


Figure 1. Steps in the Consenting Process.

Responses back to developers, as part of the Scoping exercise or specifically in connection with the published ES[8] have stressed ongoing and as-yet unresolved concerns about the possible impacts of the developments on migratory salmonids: **Atlantic salmon** (*Salmo salar*) and **sea trout** (*Salmo trutta*). These concerns are legitimate, when taking into account that:

- Atlantic salmon is listed in Annex 2 of the Habitats Directive (in freshwater environments), and 17 Scottish rivers are designated as SACs for salmon, either as a primary or a qualifying feature. Sea trout is on the UK Biodiversity Action Plan Priority Species List
- Migratory behaviour for out-migrating Atlantic salmon post smolts and returning adults, originating from or returning to many Scottish rivers including SAC rivers, *may* involve passage through the PFOW area, based on historic studies. Current research is addressing this topic in more detail. Part of this research is aimed at confirming the degree to which migrating fish may be physically co-incident[9] with either wave or tidal devices

[8] http://www.asfb.org.uk/wp-content/uploads/2011/04/ASFB-response-to-Mey-Gen-Application.pdf
[9] Note: physical co-incidence implies sufficient proximity to the installation for one of its effects to be registered in some way by the species in question: it is not solely a question of physical contact with a part of the installation.

- The exact details of physiological or behavioural responses to physical co-incidence are also a matter of current research, although there is also a body of literature that provides some guidance.

Marine Scotland, as competent authority, is required to consider whether the granting of a licence is likely to have a significant effect on any of the features for which any European sites, including SACs for Atlantic salmon or freshwater pearl mussel, were designated and their conservation objectives. If the activity is likely to have a significant effect, Marine Scotland must carry out an 'Appropriate Assessment' to determine whether there will be an adverse effect on site integrity. The overall process is called Habitats Regulations Appraisal (HRA).

The Crown Estate's Wave and Tidal programme hosted a workshop, in Thurso, on 17th and 18th April 2013, to bring together and facilitate discussion between relevant key stakeholders. The workshop covered existing data / knowledge and knowledge gaps, and stakeholders concerns regarding the potential impacts on migratory salmonids from wave and tidal developments in the PFOW area. A key component of the workshop is that it was advised by this DP (made available in early April 2013) – which sets out the issues and state of current knowledge, and which put forward possible approaches for the workshop to discuss in relation to decision-making in the consenting process.

1.3 The Regulatory Context

Marine Scotland presented the workshop delegates with details of its approach to both the processes of undertaking Environmental Impact Assessment (EIA), and Habitats Regulatory Appraisals (HRA) and (if required) Appropriate Assessments (AA), and the subsequent issuing of licences for marine renewable energy projects in the PFOW area. Delegates to the workshop were invited to consider the provisions of existing HRA and AA guidance[10], and also of the provisions in the Habitats Directive[11] and the accompanying national legislation (Conservation (Natural Habitats, &c.) Regulations 1994 as amended), in advance of attending the workshop.

Marine Scotland is in regular consultation with the European Commission as to the degree to which its potential approach is compliant with Habitats Directive obligations, whilst enabling important renewable energy projects to move forward in Scotland. Workshop delegates considered Marine Scotland's approach to consenting.

[10] E.g. http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/international-designations/natura-sites/habitats-regulations-appraisal/
[11] http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

Where the workshop (and this DP) **can** assist is in debating and agreeing recommendations for the fine detail that needs to be applied to the overarching approach, in areas such as (but not necessarily exclusively):

1. An overview of the state of knowledge about possible interactions between different wave and tidal equipment and migratory salmonids – acknowledging that there are likely to be differences between different types of equipment
2. An agreement as to what the key remaining knowledge gaps are – again recognising that these might vary depending upon the type of project (wave or tidal) and its specific location
3. A discussion about the degree to which there is access to existing relevant baseline information at local and national level, and an understanding about the proportionate and realistic requirements for developers to access, comment upon, or add to such information during the EIA and / or provision of material for HRA / AA processes
4. A review of the existing national-level research that is seeking to address knowledge gaps, and a discussion and agreement about future research that is required in order to ensure that licensing applications can be assessed on the basis of increased scientific knowledge about the chance of a development having a significant effect on an SAC.

1.4 Scope

The potential for wave or tidal energy projects to impact on a number of different receptors (species and habitats) is well recognised, and Marine Scotland and others provide guidance as to the possible significance of these, based on current and emerging knowledge. Some of the possible receptors are identified specifically in the Habitats Directive, and therefore have a high degree of inherent protection. The legislative instruments providing this protection include:

1. Regulation 39 (1) and (2) and 43 of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended): (Scottish inshore waters within 12nm)
2. Regulation 39 (1) and 43 of the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 applies (Offshore Marine Regulations)
3. The Wildlife and Natural Environment (Scotland) Act (2011) (WANE).

The status of Atlantic salmon has been discussed in Section 1.3.

The European eel is listed on Annexes IIa & Va of the Habitats Directive and on Annex III of the Barcelona Convention. It is listed in Appendix II of CITES which entered into force in March 2009. It is listed as "critically endangered" under the IUCN Red List[12]. Various management and action plans are in place for European Eels.

Based upon the responses to the wave and tidal energy Scoping Reports, the project Review Group has agreed that the scope of this project should be **limited to migratory salmonids**, since these are the species giving the most concern to stakeholders in the PFOW area, and nationally across Scotland.

1.5 Structure of the Review and Discussion Paper

In order to consider the key issues in a logical fashion, the Review and Discussion Paper is structured as follows:

- This introduction
- Background to wave and tidal energy, the devices to be deployed and indicative development timelines
- A description of the migratory salmonids sector
- A description of the potential for, and types of, interaction
- An analysis of key knowledge gaps
- A discussion and summary of findings
- Key questions for workshop discussion

[12] http://qsr2010.ospar.org/media/assessments/Species/P00479_european_eel.pdf

2 MARINE RENEWABLE ENERGY PROJECTS

Text Box 1.

The term “marine renewable energy” is used in this Discussion Paper to describe the harnessing of power found in ocean waves and tidal flows.

Wave Energy - ocean waves are created by the action of the wind on the surface of the sea. The amount of energy in the waves depends on wave height and period, which is determined by the fetch (the distance over which wave-generating winds blow).

Tidal Stream Energy - tidal currents are created by the movement of the tides, driven by the gravitational pull of the moon, and are often magnified by local topographic features such as headlands and channels

2.1 Policy Context

The transition to a low carbon economy is being driven by both an imperative to tackle climate change (by reducing the emissions of greenhouse gases) and the strategic need to secure the UK’s security of supply by avoiding over reliance on fossil fuels. Renewable energy generation, both onshore and offshore, will therefore have a central role in decarbonising UK energy supply and meeting carbon emission targets.

2.1.1 UK Targets

At a UK level, legally binding targets have been adopted to deliver 15% of all the UK’s energy – electricity, heat and transport - from renewable sources by 2020[13]. This represents an increase in the share of renewables by almost a factor of seven compared to 2008 levels (about 2.25%)[14]. To achieve this target, approximately 30% of our electricity generation will need to come from renewable sources by 2020, and whilst the Government has not specified what the mix should look like longer term, stating only that it would like to see the three low carbon technologies (nuclear, Carbon Capture and Storage (CCS) and renewables) competing on cost in the 2020s[15], it is clear that renewable energy generation, including wave and tidal generation, will form a vital part of the UK’s future energy mix.

[13] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF
[14] Renewable Energy Strategy, 2009. Available at http://www.official-documents.gov.uk/document/cm76/7686/7686.pdf
[15] House of Commons – The Future of Marine Renewables in the UK – Energy and Climate Change. 19 February 2012. Available at http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/inquiries/the-future-of-marine-renewables-in-the-uk/

The level of ambition in Scotland is even higher and in 2011 the Scottish Government announced its target to meet an equivalent of 100% of Scotland's demand for electricity from renewable sources by 2020[16]. This is underpinned by a new interim target, announced in October 2012, for renewable energy generation to account for the equivalent of 50% of Scottish demand by 2015[17].

2.1.2 Progress towards Targets

The cumulative installed renewable energy capacity in the UK reached 12.3 GW at the end of 2011, generating 34.4 TWh of electricity[18]. This represented a contribution to UK electricity generation of 9.4%. Progress towards the UK's 15% target was reported at 3.8% of energy consumption in 2011; up from 3.2% in 2010.

Scotland's renewable electricity capacity in particular has shown strong growth over the last few years and has reached a cumulative installed capacity of 5,685 MW[19]. This rapid pace of development meant that in 2011 Scotland met 35% of its electricity demand from renewable sources, beating the previous interim target of 31%. However, if Scotland is to meet its 2020 target, a three-fold increase in installed capacity will be required in just under seven years. A significant challenge.

Whilst the bulk of the additional capacity required is likely to come from offshore wind, particularly at pan UK level, the deployment of commercial scale wave and tidal arrays will provide an important contribution.

2.1.3 Value of Renewable Energy to the Scottish Economy

It has long been recognised that the renewable energy industry offers a potentially significant economic opportunity for Scotland, and the UK as a whole. And this is only likely to increase through the latter half of this decade as offshore development activity (wind, wave and tidal) picks up pace.

[16] The Scottish Government, 2011, 2020 Routemap for Renewable Energy in Scotland.
[17] The Scottish Government, 2020 Renewable Routemap for Scotland – Update, 30th October 2012.
[18] DECC, Digest of UK Energy Statistics (DUKES), 26 July 2012
[19] DECC, Digest of UK Energy Statistics (DUKES), 26 July 2012

Whilst there is a general paucity of information on employment levels associated with the industry, Scottish Renewables[20] has conservatively estimated that the renewables sector in Scotland directly supports 11,136 Full Time Equivalent (FTE) posts, of which 10,227 FTE post are in project design, development, operation and the supply chain; a further 750 FTE posts are in Further and Higher Education institutions; and 150 FTE posts in the public sector. The wave and tidal sector itself is thought directly to support 521 FTE posts, though again this is likely to be a conservative estimate given that the 'lower tiers' of the supply chain are not counted and that many employers are involved in a range of technologies which makes categorisation problematic. Employment levels are also likely to increase substantially by 2020 and it has been estimated that up to 40,000 jobs (a four-fold increase) will be required in Scotland if the 2020 electricity targets are to be met, requiring approximately £30bn of investment[21].

Project expenditure associated with wave and tidal development activity in the PFOW area will provide a significant contribution towards this, and The Crown Estate has estimated that[22]:

- Total expenditure of approximately £100 million is anticipated on the development and consenting activities
- Manufacturing of devices and the associated foundations or moorings, subsea cabling and offshore substations is expected to entail expenditure of approximately £4 billion, and the cost of installation is projected to be in the region of £2 billion
- Total capital expenditure on development of the full potential capacity is projected to be in excess of £6 billion

2.2 Current Wave and Tidal Development Activity

In contrast to onshore renewables, the wave and tidal sector in the UK, and indeed the rest of the world, is still in its infancy and is presently in transition from a focus on prototype development and testing to the first deployments of commercial scale devices and arrays.

The UK, and particularly Scotland, is at the forefront of this emerging global industry with extensive R&D programmes and internationally recognised test facilities established (including EMEC in Orkney

[20] Scottish Renewables, March 2012, Delivering the Ambition: Employment in Renewable Energy in Scotland.
[21] The Scottish Government, 2011, 2020 Routemap for Renewable Energy in Scotland
[22] The Crown Estate, May 2011, Wave and Tidal Energy in the Pentland Firth and Orkney Waters: How the Projects Could be Built.

and the Wave Hub off the South West coast of England) to accelerate the commercialisation of the sector.

Whilst current UK and international development activity has to date been limited to demonstration projects and a few small arrays comprising three to four full scale devices (see Table 1 below), significant development programmes are being pursued by a number of countries. None more so than in the UK – at the time of writing, 41 sites have been made available for wave and tidal development, representing a potential cumulative installed capacity of ~2GW. This is believed to be the largest planned programme of wave and tidal development anywhere in the world.

A number of significant hurdles (financial, technological and environmental) remain to be overcome however if there is to be sustained growth in this strategically important sector, and the enormous wave and tidal energy potential of our seas realised.

Table 1. Global Wave and Tidal Activity[23]

Country	Wave	Tidal	Description
UK	Testing	Installed	Total installed capacity presently <10MW, but still more than any other country in the world. Operational projects include e.g. Neptune Renewable Energy Ltd's 0.5MW tidal development at North Humberside, Marine Current Turbines Ltd's 1.2MW tidal development at Strangford Lough and, of course, those at EMEC.
Australia	Installed		Ocean Link and Carnegie have deployed units with plans for further device deployment in arrays. Texan Energy is also applying for consent to install 456 1MW tidal turbines in Clarence Strait, near Darwin. Environmental Impact Assessment is presently underway (Jan 2012).
Canada		Installed	Fundy Ocean Research Centre for Energy (FORCE) has been established in the Bay of Fundy, offering facilities similar to those at EMEC in Orkney. Initial deployments of a 1MW OpenHydro device by Nova Scotia Power complete. Negotiations on-going with another two developers; using MCT and Alstom Hydro technology.
China	Installed		1MW wave device installed in Guanzhou province with significant plans for additional capacity
Denmark	Installed		Testing of a scale Wave Dragon device has been on-going at the Nissum Bredning test facility since 2003.
France		Planned	EDF plan to install four Open Hydro 2MW turbines in Brittany.
India		Planned	The state of Gujurat is planning installation of 50MW of tidal stream capacity within the next 5 years.
Korea		Installed	Tidal stream capacity installed at Jindo Uldolmok in 2009 with plans for 100MW once device technology has been tested and proven.
New Zealand		Planned	Plans to harness tidal energy in the Cook Strait in place since 2008, when initial consent was awarded.
Norway	Installed		Testing completed in 2010 for a tidal sail technology at Lukksundet.
Portugal	Installed		Three Pelamis P1 devices were installed off the coast for a short period of time. Significant long term plans for wave energy still active. The WaveRider device is currently being deployed.
Spain	Installed		Development along northern Spain at Cantabria includes testing of an OPT PB40 device with plans for small arrays.
Sweden	Installed		Uppsala University has conducted wave energy tests at the Lysekil test site since 2005 with long term plans to deploy large arrays.

[23] Adapted from RenewableUK, March 2012, Marine Energy in the UK – State of the Industry Report

USA	Installed	Installed	West coast US has active development programme for the installation of wave energy devices focussed initially around Oregon. This complements the existing test deployment of OPT in Hawaii. New York's east river has housed a single Verdant 1MW turbine with plans for large arrays in the coming years.

2.3 UK Marine Renewable Energy Potential

The UK's potential wave and tidal energy resource is subject to extensive and ongoing research, and a range of estimates have been produced over the years. The Crown Estate's most recent study[24], which sought to produce a 'consolidated view' of the UK's theoretical potential, concluded that approximately 69 TWh/year (~27GW) could be generated from our wave resource and 95TWh/year (~32GW) from our tidal stream resource. Of this, two thirds of the potential wave resource and one third of the tidal stream resource is located around Scotland (Table 2 and Figures 2a/b).

Table 2. UK Wave and Tidal Resource.

Location	Wave		Tidal Stream	
	Indicative annual energy (TWh/yr)	Indicative maximum power (GW)	Indicative annual energy (TWh/yr)	Indicative maximum power (GW)
England & Wales	23	8.7	62	11
Scotland	46	18	32	20.5
Northern Ireland	-	-	1	0.5
Total	**69**	**26.7**	**95**	**32**

The relative position of the UK to the rest of Europe means that a substantial proportion of the European resource is also concentrated around the UK, and it is estimated that Scotland's waters have around a quarter of Europe's potential tidal energy resource and 10% of its potential wave resource[25].

[24] The Crown Estate, October 2012, UK Wave and Tidal Key Resource Areas Project – Summary Report. Available at http://www.thecrownestate.co.uk/search?keyword=demonstration+project+leasing (accessed on 18 January 2013)
[25] Scottish Development International, Wave and Tidal Energy Key Facts. Available at http://www.sdi.co.uk/sectors/energy/sub-sectors/wave-and-tidal-energy/wave-tidal-key-facts.aspx

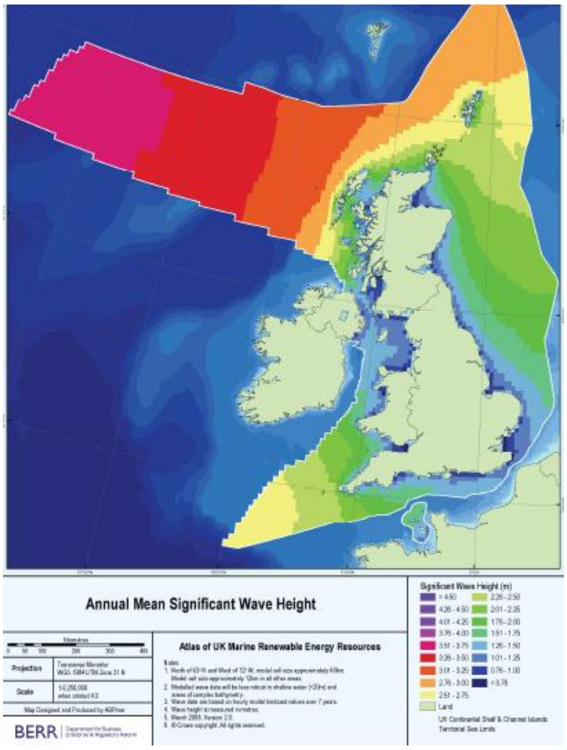


Figure 2a. UK Wave Energy Resource[26]

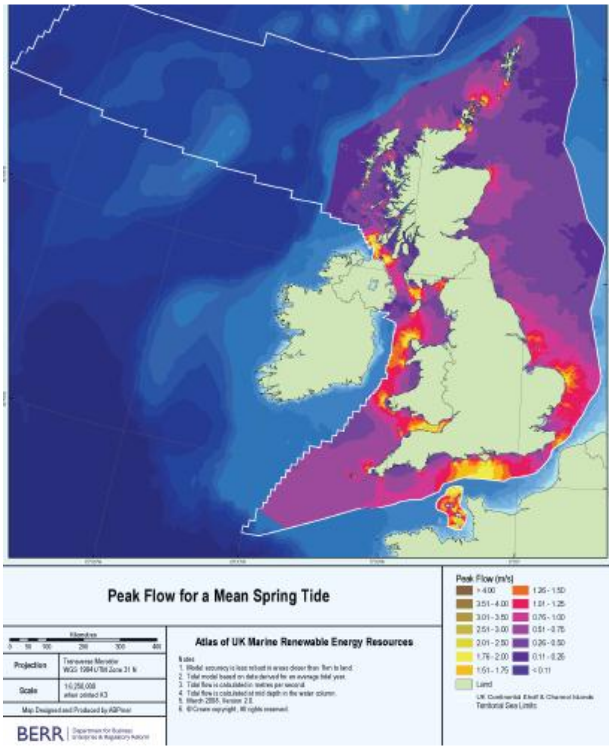


Figure 2b. UK Tidal Energy Resource

The PFOW area, in particular, is one of the key resource areas in the UK. The hourly surface flow velocities of the tidal stream in the Pentland Firth are shown in Figures 3a and 3b below[27]. Darker grey shading indicates higher velocities. Two observations are particularly relevant, which are discussed further in Section 4:-

1.) Tidal stream velocities are significant, reaching up to 6m/s; and
2.) The strongest currents are associated with the Outer Sound, between the islands of Stroma and Swona.

[26] BERR, March 2008, Atlas of UK Marine Renewable Energy Resources: Atlas Pages – A Strategic Environmental Assessment Report.
[27] A. Owen and I.G. Bryden, Resource Analysis of the Pentland Firth. Available at http://www.see.ed.ac.uk/~shs/Tidal%20Stream/Draft%20Pentland%20Firth%20Resource%20Assessment%20Paper.pdf

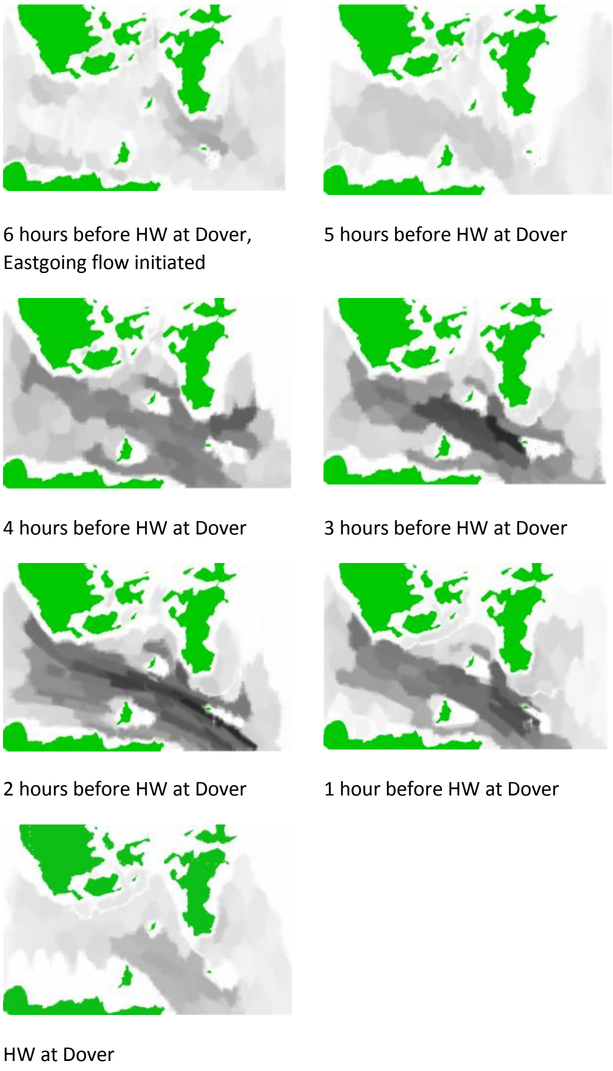


Figure 3a. Tidal current strengths in PFOW – Eastgoing flows

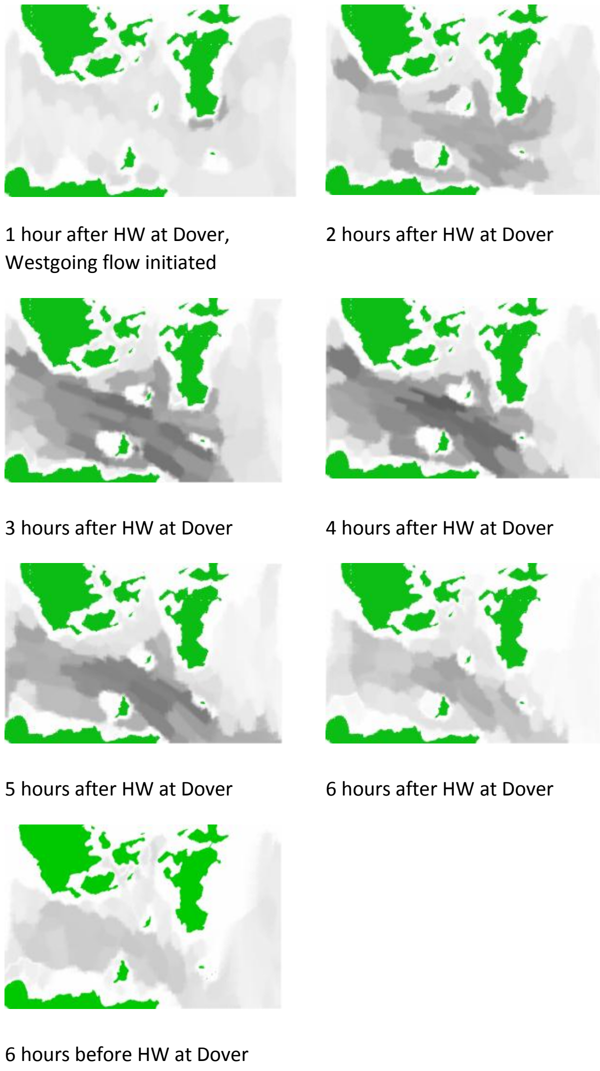


Figure 3b. Tidal current strengths in PFOW – Westgoing flows

The Carbon Trust's assessment of the UK's resource that could *practicably* be extracted using foreseeable wave and tidal device technologies without "significant" impact on the economics of energy extraction, spatial constraints or on the environment, concluded that:[28,29]

- Tidal - a total of 20.6 TWh per year could practically be extracted from 30 key tidal stream sites in the UK. Applying different acceptable impact levels could increase the developable resource by up to 40% (28.8TWh per year)
- Wave - between 32 and 42 TWh per year, equating to an installed capacity of roughly 10GW to 13GW, though could be as high as 70 TWh per year (~21GW).

[28] Carbon Trust, June 2011, UK Tidal Current Resource & Economics.
[29] Carbon Trust, October 2012, UK Wave Energy Resource, prepared by AMEC Environment and Infrastructure UK Limited.

Based on the above, the Carbon Trust estimated that:-

1.) The combined wave and tidal resource in the UK could provide 20% of the UK's electricity if fully developed
2.) A realistic scenario is for 13.2GW of installed capacity (approximately two and a half times Scotland's current cumulative installed renewable energy capacity) by 2050 (~11%).

2.4 Wave and Tidal Sites in the PFOW area

Text Box 2.

The Crown Estate owns almost the entire seabed out to 12 nautical miles (nm) and around half the UK's foreshore, tidal beds and estuaries.

The Energy Act 2004 also gives The Crown Estate the power to issue leases for renewable development out to the edge of the UK continental shelf, within the Renewable Energy Zone.

The PFOW area was the first area to be made available for the deployment of commercial-scale wave and tidal energy arrays in the UK.

The PFOW leasing round, undertaken between 2008 – 2010, resulted in 11 commercial-scale projects being awarded "Agreements for Lease" (AfL) – short duration contracts which give the developers exclusive rights over defined areas of seabed for site investigation and other project development works. The AfL sites are essentially areas of search. In the event that all necessary consents are obtained, leases will be granted, typically over much reduced areas, allowing the development companies to construct and operate the projects.

If these eleven projects proceed according to current development plans, this represents a potential generating capacity of approximately 1.6GW, which would be sufficient to provide electricity for around 1.2 million homes. Whilst this leasing round has now closed, an additional AfL was awarded in the PFOW area in November 2012 for a 30MW tidal energy demonstration project in Lashy Sound, between the islands of Eday and Sanday in Orkney.

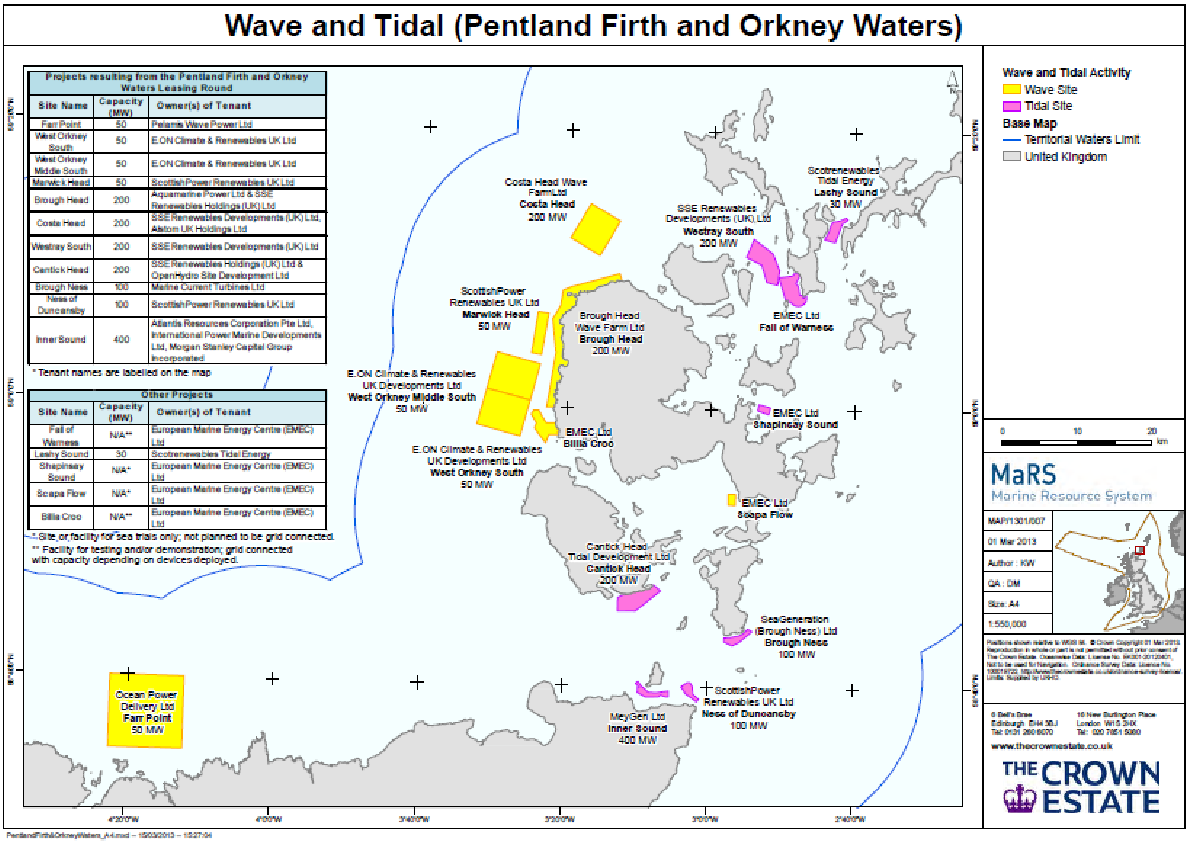


Figure 4. PFOW AfL Areas.

2.5 Developer Programmes and Phasing

The majority of developers have proposed to phase (subject to separate consent and licensing requirements) device deployment (see Table 3). For wave energy developers, this initial phase typically consists of developments of between 10MW and 50MW of installed capacity. Phase 1 tidal developments are slightly larger in scale, ranging between 30MW and 100MW.

Table 3. PFOW Project Developers and Sites

Developer	Sites	Wave		Tidal	
		Initial Capacity (MW)	Full Capacity (MW)	Initial Capacity (MW)	Full Capacity (MW)
Aquamarine Power Ltd & SSE Renewables Holdings (UK) Ltd	Brough Head	50	200		
SSE Renewables Developments (UK) Ltd	Costa Head	10	200		
Pelamis Wave Power Ltd	Farr Point	15	50		
ScottishPower Renewables UK Ltd	Marwick Head	9	50		
E.ON Climate & Renewables UK Ltd	West Orkney South	10	50		

E.ON Climate & Renewables UK Ltd	West Orkney Middle South	10	50		
ScottishPower Renewables UK Ltd	Ness of Duncansby			95	95
MeyGen Ltd	Inner Sound			86	400
SSE Renewables Developments (UK) Ltd	Westray South			35-45	200
SSE Renewables Holdings (UK) Ltd & OpenHydro Site Development Ltd	Cantrick Head			30	200
Marine Current Turbines Ltd	Brough Ness			tbc	100
	Totals		**600**		**995**

At the time of writing, the anticipated development programmes are as set out in Table 4 below. These programmes are subject to a number of external factors, not least receipt of all necessary consents and licences, and grid availability. In the latter phases, potential supply-side constraints - e.g. device manufacture, availability of required vessels etc. – may also impact these development programmes. These figures (mostly taken from published sources, such as scoping reports) should therefore be treated as indicative only.

Several points are particularly relevant:

1.) Actual phasing and timing of PFOW projects is subject to change and the details presented here should therefore be treated as indicative only

2.) The majority of developers have proposed to phase device deployment

3.) Build-out, particularly for the larger Phase 1 projects, will be staggered for some projects - e.g. Brough Head, Inner Sound and Ness of Duncansby

4.) There will be no deployment of wave devices prior to 2015

5.) MeyGen is likely to be the first to deploy tidal devices in the Pentland Firth, which subject to receipt of all necessary consents will be staggered from 2014, initially with six devices. No other developer is currently planning to install tidal devices prior to 2018

6.) Applications for the necessary consents/licences from regulators will obviously be made in advance of planned deployment dates (maybe up to two or more years).

Table 4. Phases of Development of PFOW Projects.

		Device	2013	2014	2015	2016	2017	2018	2019	2020+
Wave	Brough Head^	Oyster						Phase 1a: 10MW (10 devices). Phase 1b: up to 40MW (40 devices)		further 150MW (150 devices)
Wave	Coast Head Wave Farm^	AWS-III							10MW (4 devices)	further 190MW (95 devices)
Wave	Farr Point Wave Farm"	P2e Pelamis			10MW (10 devices)				further 40MW (40 devices)	
Wave	Marwick Head	P2 Pelamis						9MW (12 devices)		further 40MW in 2 phases (40 devices)
Wave	West Orkney South	P2 Pelamis				10MW (13 devices)			further 40MW (53 devices)	
Wave	West Orkney Middle South	Technology neutral				10MW			further 40MW	
Tidal	Ness of Duncansby	ANDRITZ HYDRO						30MW (30 devices)		further 65MW in 2 phases (65 devices)
Tidal	Inner Sound~	ARC AK1000 / TGL 1MW		Phase 1a: 2-10MW (2-10 turbines). 6 currently proposed.	Phase 1b: further 10-20MW (10-20 devices); Phase 1c: further 56-74MW (56-74 devices) depending on earlier deployments.					further 312MW (312 devices)
Tidal	Westray South^	Shrouded / unshrouded 1MW turbines						30-45MW (up to 45 devices)		further 155MW-170MW (155-170 devices)
Tidal	Cantrick Head^	OpenHydro							30MW (up to 30 devices)	further 170MW (up to 170 devices)
Tidal	Brough Ness	SeaGen						Pre-scoping. Likely 3 phases, from 2018.		

Key

- Phase 1 deployments (yellow)
- Phase 2 deployments (orange)

Assumptions:

~ development programme beyond 2016 uncertain.

^ balance of all phases to be grid connected by 2025.

" anticipate deployment of the Pelamis P2e (next iteration of the machine), which is likely to have a higher rated capacity of approximately 1MW.

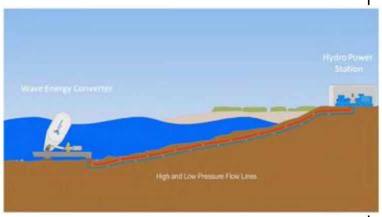
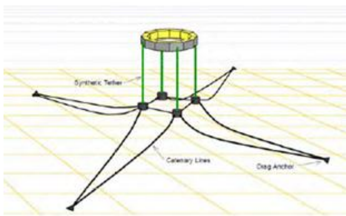
2.6 Wave and Tidal Devices to be Deployed

Whilst over 240 wave and tidal concepts are presently under development[30], three broad types of wave energy converters (attenuators, point absorbers and oscillating wave surge converters) and one broad type of tidal turbine (horizontal axis) are proposed to be deployed in PFOW. The specifications of the devices, and the likely spacing of the devices within an array, are provided in Table 5 below.

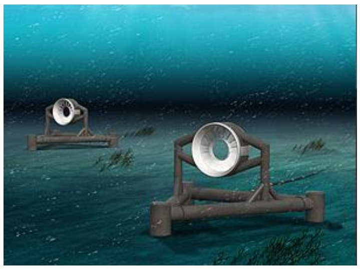
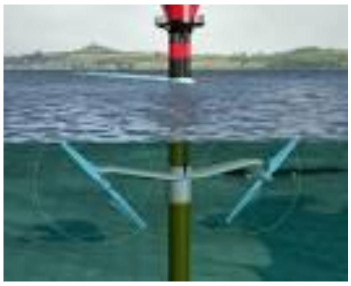
Whilst in most cases the specific make and model of the device(s) to be installed during the initial phases are known, a number of developers are presently reviewing available options (albeit within a given type of technology – e.g. horizontal axis turbines) and it is possible that whilst the type and maximum parameters will be known, the exact device to be installed may not have been selected prior to submission of consent and licence applications.

[30] http://www.emec.org.uk/

Table 5. MRE Device Summaries[31]

Device	Device Description	Dimensions and Array Spacing	
Pelamis WECs (Attenuator)	The Pelamis machine is made up of five tube sections linked by universal joints which allow flexing in two directions. The machine floats semi-submerged on the surface of the water and inherently faces into the direction of the waves. As waves pass down the length of the machine and the sections bend in the water, the movement is converted into electricity via hydraulic power take-off systems housed inside each joint of the machine tubes, and power is transmitted to shore using standard subsea cables and equipment. The machine operates in water depths greater than 50m and is typically installed 2-10km from the coast. The machine is currently rated at 750kW. The P2e (under development) is likely to have a higher rated capacity at ~1MW.	**Dimensions** P2 Pelamis is 180m long, 4m in diameter and approximately 1,350 tonnes in weight (mostly sand ballast). **Array Spacing** On a typical site, 15MW of generating capacity (20 devices) could be installed within 1km2 – 2km^2.	
Oyster WECs (Oscillating wave surge converter)	Oyster is a near shore wave energy device, typically deployed in depths of between 10m to 15m. The oscillating action of the waves against the WEC (or flap) drives hydraulic pistons which pump pressurized water to the shore through a closed loop pipeline system. Onshore hydro-electric plant converts the hydraulic pressure and flow into electrical power. Each Oyster is rated at 1MW.	**Dimensions** The flap is between 26 and 33m wide (parallel to the shore), and 3.5m thick (perpendicular to the shore), approximately 13m high (top of flap to hinge point), with a hinge axis depth of approximately 9m below MSL. **Array Spacing** Devices will be deployed in staggered lines with minimum separation distances between the devices of 10m (horizontal axis) and 25m (perpendicular axis). Actual spacing will be determined by seabed bathymetry, and will generally be greater and irregular.	
AWS-III WECs (Point absorber)	AWS-III is a multi-cell array of flexible membrane absorbers which covert wave power to pneumatic power through compression of air within each cell. The cells are inter-connected, thus allowing interchange of air between cells in anti-phase. Turbine-generator sets are provided to convert the pneumatic power to electricity. Each device is rated at 2MW.	**Dimensions** A typical device will comprise an array of 12 cells, each measuring around 16m wide by 8m deep, arranged around a circular structure with an overall diameter of 60m. **Array Spacing** A five device array is likely to occupy approximately 1.6km^2.	

[31] Summarised from developer Scoping Reports and manufacturer websites

Device	Device Description	Dimensions and Array Spacing	
Shrouded horizontal axis tidal turbines (e.g. Open Hydro)	Shrouded devices rotate within a fixed duct. The OpenHydro tidal turbine is a horizontal axis direct drive permanent magnet generator with symmetric, fixed pitch blades. The center section of the rotor is open. The Open Hydro device has a normal blade rotation rate of 10rpm, and is rated at up to 2MW.	**Dimensions** The Open Hydro turbine has a 16-20m rotor diameter, 13-15m hub height and a footprint on the seabed of approximately 30m x 30m (for the 16m blade diameter turbine). **Array Spacing** Devices spacing is likely to be similar to horizontal axis turbines at 2.5 x rotor diameter laterally and 10 x rotor diameter downstream.	
Unshrouded horizontal axis tidal turbines	This type of turbine resembles the common horizontal axis (onshore) wind turbine. Tidal energy is converted in both current directions either by pitching of the blades or rotation of the nacelle. The devices are designed for installation in water depths of between 30m and 100m. Blades typically rotate up to 20rpm – this compares to 25rpm on an equivalently rated onshore wind turbine (the shorter blade also means that the tip speed is considerably lower at around 21m/s compared to 70m/s for the wind turbine). Speeds in air cannot be directly equated with speeds in water. At the present time, most devices are rated at 1MW.	**Dimensions** These devices typically have a hub height of between 14-26m and a rotor diameter of 18 to 26m, giving a tip height from the seabed of between 23m and 39m. **Array Spacing** Device spacing is likely to be in the region of 2.5 x rotor diameter laterally and 10 x rotor diameter downstream.	
Unshrouded horizontal axis tidal turbines - surface piercing structure (e.g. Seagen S)	The SeaGen S system consists of twin power trains mounted on a crossbeam. The cross beam can be raised above the water for routine maintenance by winching it up the monopole support structure. Automatic 180 degree pitch controlled rotor blades allows energy capture on both ebb and flood tides. SeaGen S is suitable for marine environments in water depths up to 40m and achieves rated power in tidal currents of greater than 2.4m/s. The SeaGen S Mk 2 (under development) is rated at 2MW.	**Dimensions** Rotor diameter of between 16m and 20m. Cross beam approximately 27m. Can be installed in water depths of between 24-40m. **Array Spacing** Will be optimised locally.	

2.7 How the Projects might be Built

Whilst the following section provides an overview as to how the projects *might* be built, these details are not definite and in reality, particularly for the more distant second phases, may well be different as a result of advances in technology and/or construction methods and greater knowledge of risk and how to mitigate it.

2.7.1 Device Installation

Whilst the exact method of installation will vary between device concepts (wave – near shore / offshore, and tidal) it is understood that between 10 and 20 devices will typically be deployed per year, assuming no supply-side constraints (as discussed in Section 2.5). It is also likely that on-site work and device installation will be undertaken throughout the calendar year; weather being the critical determining factor.

In most cases, the mooring systems and foundations can be installed prior to transportation of the devices to the site. For multi-device arrays, this allows mooring and device installation to occur concurrently on different parts of the site, thereby reducing the duration of the weather window required.

Wave – Near shore: The Oyster wave energy converter, the only near shore device currently being proposed, will be affixed to a monopole support structure drilled and grouted into the seabed. This will most likely be undertaken by a jack-up rig. The device will then be barged or wet-towed to site, positioned over the pre-installed sub-structures and lowered into place and secured.

Wave - Offshore: Depending on the exact type of device to be installed, and the seabed characteristics at the site, between four and eight anchors could be required for each wave device installed. In the majority of cases, however, array configurations and the design of the mooring systems to be used by the developers - in terms of the number, spread and types of anchors to be used - has still to be determined and will be informed/optimized after detailed site and geophysical seabed investigations have been undertaken. The typical types of anchors that may be used include: drag embedment anchors, piles, vertical load anchors, and gravity based anchors (see Figure 5).

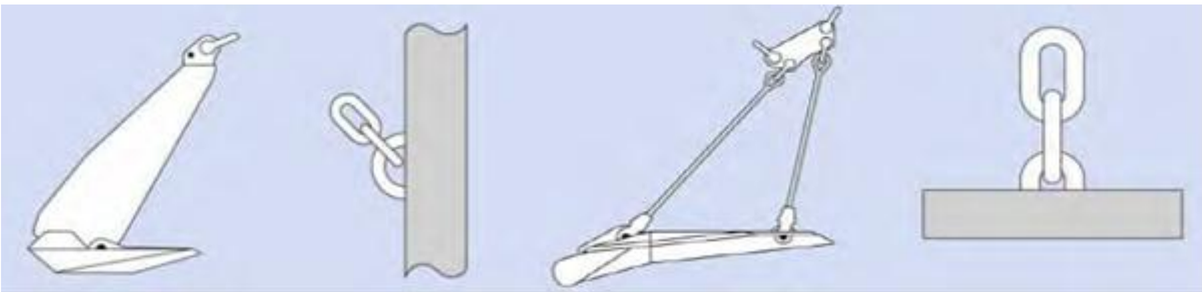


Figure 5 Possible Anchoring Solutions. Source – Costa Head[32]

A variety of vessels may be utilized to install mooring components, from multi-cats and anchor handler tugs (AHTs) to dive support vessels.

The devices (either fully or partially commissioned onshore) will be barged or wet-towed to site and attached to the pre-installed mooring system. Installation would typically require two medium sized vessels, taking a few hours per device.

Tidal: These devices are typically affixed to one of three types of support structure:

Gravity Base Structure (tripod) **Drilled pin pile tripod** **Monopile**

Figure 6 Tidal Turbine Mooring Systems[33].

The pin pile and monopole foundation structures will be drilled and grouted into the seabed, rather than "driven" by high capacity impact hammers as is the case for offshore wind installations and certain oil and gas platforms. This is important in terms of potential noise impacts, as driven piles result in significantly higher sound intensities – see part 4.2.

[32] SSER, May 2012, *Costa Head Wave Farm – Offshore Scoping Report. Prepared by Xodus Group*

[33] MeyGen Environmental Statement. Available at http://www.meygen.com/the-company/reports-and-documents/

Tidal devices will also be barged or wet-towed to site. Each device will be positioned over the pre-installed pins / sub-structures (where required), lowered into place and secured.

2.7.2 Umbilicals and Power Cables

A variety of subsea control umbilicals and power cables will be required for each development. The final layout of the devices, and therefore length of cables runs, will be driven by a number of key factors, including resource potential, site seabed conditions and bathymetry. The length of cable runs for phase 2 deployments will also be contingent on any optimization to the layout of the array resulting from the knowledge gained during initial deployments or from other new studies.

Inter-array cabling is likely to take one of two forms: 1.) individual umbilical cables per device (likely for phase 1 deployments), or 2.) a number of interconnected "daisy-chains" (umbilicals connecting multiple devices).

It is likely that most offshore cable laying operations will be undertaken by specialized cable laying vessels using Dynamic Positioning systems.

Wave: Inter-array cabling is likely to be installed directly on the seabed and, as required, either buried by a cable plough or jetting system, typically to a depth of 1-1.5m depth below seabed, or protected by rock armouring and concrete mattresses. For the Pelamis arrays, however, the inter-array cables will be suspended mid-water column (~15-20m depth) with the use of cable buoys and weights.

Tidal: Inter-array cabling for tidal sites will be similar to the requirements for offshore wave sites, albeit that the majority of the cabling (where possible) is likely to run in the direction of the tidal flow.

2.7.3 Offshore Substations

Offshore substations (supported on a jacket structure, moored floating structure, or pinned monopole type structure), may be utilised for the (offshore) projects. However, this remains the subject of ongoing industry research, including the potential for sub-sea hubs, and there will likely be strong site specific drivers as to whether or not such facilities will be required and, if they are, the exact type of solution that may be adopted.

The purpose of the substation is to collect the electricity generated from the installed devices via the inter-array cabling and 'step-up' the voltage from say 33kV to 132kV before transmitting to shore via the export cables. This reduces the current carried by the cable, which in turn reduces transmissions losses and improves the operational efficiency of the array. The reduced current carried by the cable also has an important bearing on Electro Magnetic Field (EMF) emissions, which are discussed further in part 4.2.3.

The substation would likely be located in close proximity to the arrays, albeit that this will, at least in part, be determined by the design and route of the export cable.

2.7.4 Export Cabling

Installation methods for the export cabling associated with offshore sites would be similar to that required for inter-array cabling. The route and protection requirements (buried / rock armour / concrete mattresses) will be determined following detailed project design work and the results of site and cable route surveying. Specialist cable laying vessels would be required for the installation works.

The number of export cables likely to be required for a given development is again the subject of current industry research, but could range from individual export cables per device to collection at an offshore platform or sub-sea hub (see 2.7.4) prior to export to shore. Ultimately, any solution utilised will have to be proven, both technically and commercially.

Information on wider grid infrastructure requirements, including offshore elements, can be found in The Crown Estate's Onshore Infrastructure Information Note[34].

2.7.5 Operation and Maintenance

All devices will operate autonomously, and on-site activities will only be required for inspection and maintenance purposes.

Current estimates are that planned inspections and light maintenance works would likely be required on a bi-annual / annual basis, which may or may not require the use of divers. More comprehensive device overhauls are likely to take place every five years, which will require the devices to be detached from their mooring systems and support structures and taken to port. Device overhauls will be staggered to ensure continued operation of the arrays. For the larger arrays, it is likely that in any one year there would be work on site removing and overhauling devices.

[34] The Crown Estate, 2012, Pentland Firth and Orkney Waters Onshore Infrastructure Information Note, prepared by Parsons Brinkerhoff and available at www.thecrownestate.co.uk

2.7.6 Decommissioning Requirements

Decommissioning requirements will be determined at the time, but will require to be undertaken to a standard meeting prevailing industry best practice. A Decommissioning Programme, required under the Energy Act (2004), will be agreed with DECC in advance of works commencing.

3 MIGRATORY SALMONIDS

3.1 Status of Migratory Salmonids

3.1.1 Distinction between Atlantic Salmon and Sea Trout

This project has tended to focus on Atlantic salmon more than on sea trout. The reasons for this focus are pragmatic:

1. Both Atlantic salmon and sea trout are included on the list of Priority Marine Features – the habitats and species of greatest conservation importance in inshore waters. However, Atlantic salmon are also protected under the terms of the Habitats Directive, which can trigger a requirement for HRA and AA.
2. According to our best understanding, sea trout (as a species) do not undertake long distance migrations around Scotland's coast to the same degree as Atlantic salmon, although there is a paucity of information about the location and behaviour of sea trout in Scottish coastal waters. Whilst there is no suggestion that a significant percentage of Scotland's entire population of sea trout pass into or out of the PFOW area on an annual basis, there are important local stocks in the area.

3.1.2 Habitats Directive Considerations

Atlantic salmon enjoy a degree of legal protection, summarised briefly in Section 1.2. Of these 'protections', the one most often cited and considered is that afforded by the Habitats Directive, and specifically related to the Scottish SAC rivers associated with salmon.

A total of 17 rivers[35] have been designated as SACs, 11 with salmon listed as a primary interest, under the EU Natura 2000 obligations. The fresh water pearl mussel (*Margaritifera margaritifera*) is also a species of interest under EU Natura 2000 obligations, and is of relevance because of the role of salmonids as host during part of its life cycle. The salmon SAC rivers are shown in Figure 7, and it should be noted that three of the 17 enter the sea within the PFOW area, and another one (Berriedale and Langwell) is close to the area. Geographical proximity of SAC rivers to the PFOW area may not be the only consideration with respect to licensing, depending upon an understanding of

[35] Tweed, Tay, South Esk, Dee (Aberdeenshire), Spey, Berriedale & Langwell, Thurso, Naver, Little Gruinard, Grimersta (Langavat), Bladnoch, Endrick*, Teith*, Moriston*, Oykell*, Borgie*, North Harris*

* rivers where Atlantic salmon are included as a species of interest, but where the site was not designated primarily for salmon.

migratory behaviour to and from other rivers in Scotland. Table 6 shows which of the 17 SAC rivers also have freshwater pearl mussel as a species of interest.

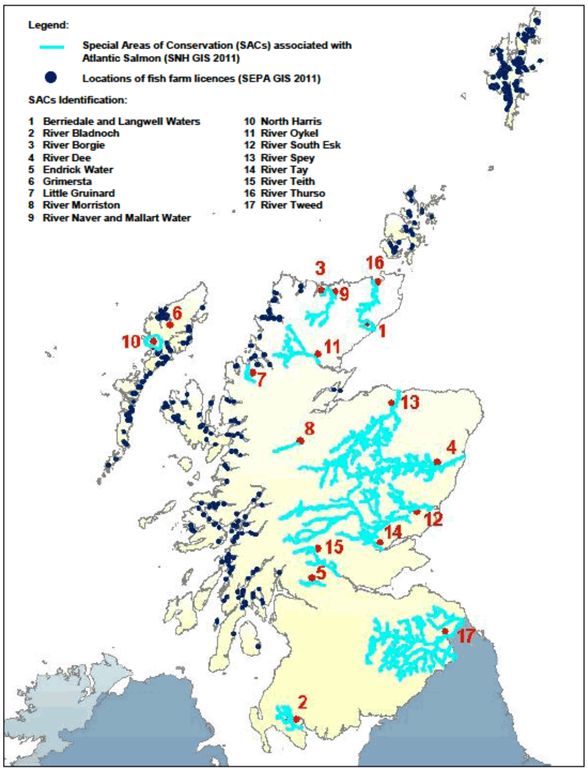


Figure 7. Scottish Salmon SAC Rivers. Source: Marine Scotland.

Table 6. Scottish SAC rivers designated for Atlantic salmon and freshwater pearl mussel.

SAC code	SAC name	Atlantic Salmon	Freshwater pearl mussel
UK0012691	River Tweed	Yes	
UK0012935	North Harris	Yes	Yes
UK0012995	River Borgie	Yes	Yes
UK0019811	River Spey	Yes	Yes
UK0019840	Endrick Water	Yes	
UK0030088	Berriedale and Langwell Waters	Yes	
UK0030183	Little Gruinard River	Yes	
UK0030249	River Bladnoch	Yes	
UK0030251	River Dee	Yes	Yes
UK0030255	Langavat	Yes	
UK0030259	River Moriston	Yes	Yes
UK0030260	River Naver	Yes	Yes
UK0030261	River Oykel	Yes	Yes
UK0030262	River South Esk	Yes	Yes
UK0030263	River Teith	Yes	
UK0030264	River Thurso	Yes	
UK0030312	River Tay	Yes	

Atlantic salmon is a migratory species, and even though a proposed 'project' may lie out-with the physical boundary of a designated SAC, the possible impact of a project on some of the individuals originating from or returning to the SAC represents a possible 'pathway' for effect on the SAC, triggering a requirement to undertake an HRA in the first instance, and if necessary an AA – see Section 1.2. Marine Scotland's approach to HRA and AA for wave and tidal energy projects in the PFOW area has been briefly discussed in Section 1.3, and any further consideration on this topic was a matter for Marine Scotland to comment upon during the workshop.

The status of all designated SACs in Scotland is monitored, and reported according to different but proscribed categories, by SNH[36]. A separate detailed analysis of the status of SAC rivers based on catch statistics was undertaken by MSS in 2010[37], and its conclusions were:

The key long term trend results were:

- For the Spring stock component catches:
    - 94 % are declining (15 out of 16 rivers)
    - 0 % are increasing (0 out of 16 rivers)
    - 6 % are largely stable over the long term(1 out of 16 rivers)
- For the Summer stock component catches:
    - 19 % are declining (3 out of 16 rivers)
    - 72 % are increasing (10 out of 16 rivers)
    - 19 % are largely stable over the long term (3 out of 16 rivers)
- For the Autumn stock component catches:
    - 6 % are declining (1 out of 16 rivers)
    - 82 % are increasing (13 out of 16 rivers)
    - 12 % are largely stable over the long term (2 out of 16 rivers)

The MSS overview of SAC rivers status is presented here as background context. However, it is important to note that the above-cited analysis undertaken for the Scottish Mixed Stock Salmonids Fisheries Working Group (SMSSFWG), along with a considerable amount of additional research, provided no evidence which the Group could put forward to Scottish Ministers in support of any action that might be taken on conservation grounds, with respect to curtailing or limiting existing commercial salmon netting in Scotland.

[36] http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/site-condition-monitoring/
[37] Note that 2 smaller rivers were combined for analytical purposes, resulting in 16 considered in total, rather than 17. These were the Naver and the Borgie: two of the SAC rivers in the PFOW area

3.1.3 Status of Migratory Salmon Stocks

The long term trends for Atlantic salmon and sea trout stocks are discussed in other reports and studies[38], and it is not necessary to repeat these in detail except to note that there has been a long term decline in the numbers of both species, as measured by fishery catch data. The North Atlantic Salmon Conservation Organisation (NASCO) observes[39] that: "*Monitoring in rivers around the North Atlantic over the last thirty years has confirmed that there has been a significant decline in overall marine survival, particularly for southern European and North American stocks. Major restrictions on exploitation of salmon have been introduced but, to date, the salmon stocks have not responded. Lack of understanding of the factors affecting survival of salmon at sea is the key obstacle to rational management of the Atlantic salmon and to the ability to rebuild stocks*."

More recently, NASCO (2012) has commented upon the increasing trend of marine mortality, mentioned above, in the context of effects of climate change on the marine environment[40].

Wave and tidal energy developments have the potential to contribute towards a lower-carbon energy mix, and therefore towards possible reduced long term effects of climate change. Whilst this aspect of the PFOW projects in no way detracts from the need for a rigorous HRA approach to applications, the HRA guidance (4.21) does acknowledge that some impacts on a European site may be positive. In this scenario the benefits are likely to be long term – but they remain a possibility that should be kept in mind.

3.2 Sectors interacting with Atlantic Salmon and Sea Trout

Under the terms of the HRA guidance, every project must be assessed on its own merits, and evidence of approval of a similar project elsewhere is not sufficient in terms of decision-making.

Nevertheless, it is important to stress that knowledge about migratory salmonids and pressures upon them, man-made (anthropogenic) or natural, is based upon many years of practical experience and scientific study. Even for relatively new sectors such as aquaculture, which still causes some concerns for migratory salmonids interests, there has been almost 40 years of experience of the different types of interaction that can occur.

[38] See for example: http://www.scotland.gov.uk/Publications/2010/03/31154416/0 and http://www.nasco.int/pdf/reports_other/Salmon_at_sea.pdf
[39] http://www.nasco.int/pdf/implementation_plans/IP_Scotland.pdf
[40] http://www.nasco.int/pdf/reports_other/Salmon_at_sea.pdf

Wave and tidal developments are entirely new sectors in some regards, but in fact many of the component parts of these developments are long-established in the marine environment – and have presumably been interacting with migratory salmonids during their history. As Scottish Natural Heritage (SNH) points out: "*Atlantic salmon are subject to many pressures in Europe, including pollution, the introduction of non-native salmon stocks, physical barriers to migration, exploitation from netting and angling, physical degradation of spawning and nursery habitat, and increased marine mortality*[41]**.**" In terms of encountering man-made technologies, there has been a long history of subsea cabling, gravity / embedment anchors, marine shipping (with noise and rotating screws), harbour and breakwater installations, and others. Figure 8 provides a graphical illustration of how some of these developments have been deployed in the marine environment.

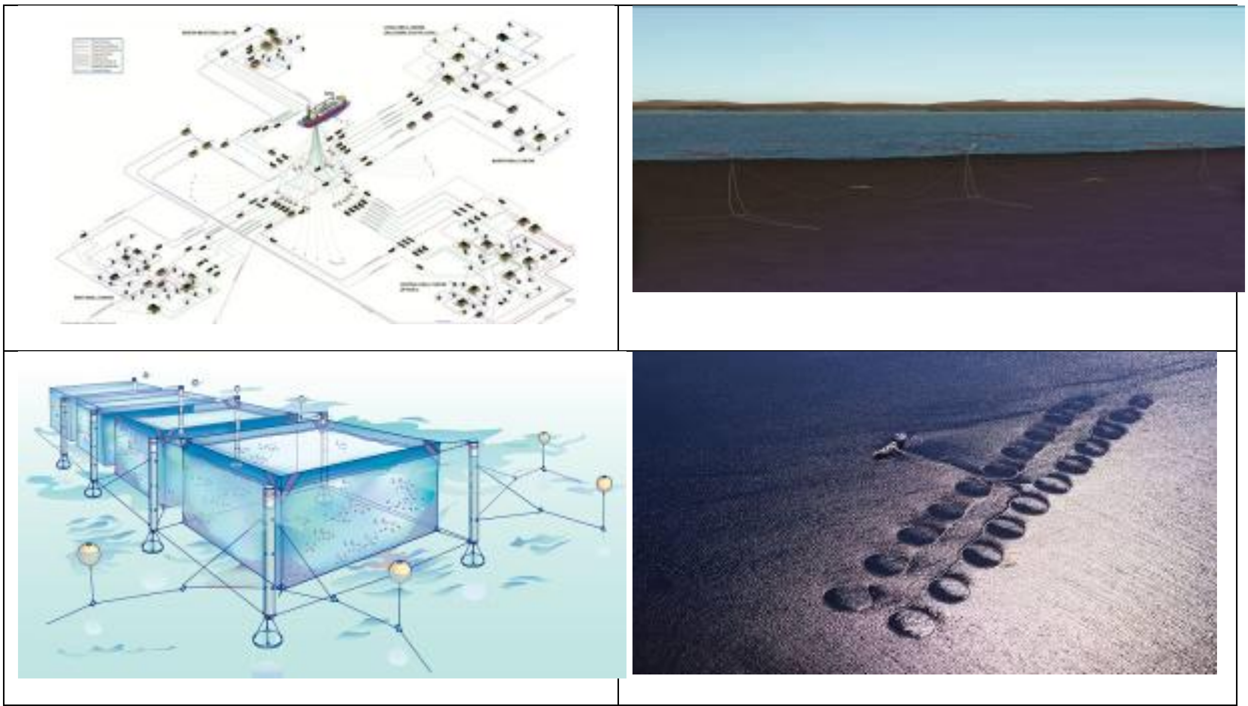


Figure 8. Clockwise from top, a Floating Production Storage Offloader (FPSO) currently present off the west coast of Shetland in Schiehallion, note catenary mooring system. Pelamis wave energy array, an example of a marine cage fish farm mooring system and configuration.

Wave, tidal and offshore wind energy are relatively new potential impactors on migratory salmonids. The life cycle stages of a salmon from the point of hatching from an egg in a river to reaching adult feeding grounds in the North Atlantic, are clearly complex, and there are many interactions between the fish and many other factors along the way.

[41] http://www.snh.org.uk/salmonlifeproject/scottish_salmon.asp

3.3 Value of the Sector to the Scottish Economy

The most definitive study on the value of freshwater fisheries and angling to the Scottish economy was published by Radford *et al*, 2004[42]. Workshop delegates wishing to know more about the nature of the employment and financial indicators should read the source material. Although now somewhat dated, some of the report's key findings were:

1. Anglers spend a total of £113million on angling in Scotland, with salmon and sea trout anglers accounting for over 65% (73m) of this total
2. £44.5m of expenditure would be lost across the whole of Scotland if salmon and sea trout fishing were to cease completely
3. 1,776 full time equivalent (fte) jobs would be lost in Scotland if salmon and sea trout fishing were to cease completely
4. £20.7m and £15.3m of expenditure would be lost in the Highland region and North East Scotland (respectively) if salmon and sea trout fishing were to cease
5. 781 and 688 fte jobs would be lost in the Highland region and North East Scotland (respectively) if salmon and sea trout fishing was to cease.

Further consideration of PFOW local salmon economics is contained in Section 3.4, but the key point is that a national perspective is relevant if the PFOW area is an important focal point for salmon migration to and from many of Scotland's rivers – see Section 4.

It should be noted that the phrase "*were to cease completely*" in the Radford summary above is not intended to be alarming – it is simply the way that economists assess such indicators.

3.4 Migratory Salmonids in the PFOW area

As previously indicated, there are several levels of interest with respect to the proposed wave and tidal projects in the PFOW area, in relation to migratory salmonids:

- Local impacts on a single project-by-project basis
- Local impacts on a cumulative / in-combination basis
- Wider impacts (single project or cumulative / in-combination) as a result of salmonids migrating through the area from or to other parts of Scotland.

[42] http://www.scotland.gov.uk/Publications/2004/03/19079/34369

Current knowledge about salmonids', and particularly Atlantic salmon's, migration behaviour through the PFOW area is considered in Chapter 4 of this DP.

Table 7 provides some information about the local situation, drawing upon MSS statistics for 2011, and also drawing upon inflation-indexed indicators from the Radford report of 2004 (see Section 3.3).

Table 7. Atlantic salmon caught (all methods, retained and released) in North Region – 2011.

	Atlantic Salmon			
	Retained	% of Scotland	Released	% of Scotland
Kyle of Sutherland	646	1.5%	2974	4.7%
Fleet and Brora	159	0.4%	443	0.7%
Helmsdale	475	1.1%	1678	2.6%
Berriedale to Wick	1010	2.3%	487	0.8%
Thurso and Forss	1741	4.0%	1678	2.6%
Halladale and Strathy	4270	9.7%	717	1.1%
Naver and Kinloch	391	0.9%	2116	3.3%
Hope and Grudie	144	0.3%	470	0.7%
North Total	8836	20.1%	10563	16.6%
Scotland Total	43923		63810	

In total, the North region[43] catches are just over 20% of all Scotland's Atlantic salmon catches (all methods).

Table 8. Atlantic salmon caught and retained by method in North Region – 2011.

	North	
	Atlantic Salmon	% of Scotland
Rod and Line	4013	16.6%
Net and Coble	33	0.5%
Fixed Engine	4790	34.7%

In terms of catching method, the North region is significant in terms of the percentage of all Atlantic salmon that are caught and retained by fixed engine commercial fishing: 34.7%.

[43] North region is a statistical area defined by MSS

Based on Radford 2004 (op cit), with angling expenditure recalculated with inflation since 2004[44] and based on the 2011 statistics, the North region:

- Has total angling expenditure of £14.67 million; and
- Has supported employment of 360 FTE jobs.

[44] http://www.rateinflation.com/inflation-rate/uk-historical-inflation-rate

4 INTERACTIONS

4.1 Introduction

As discussed briefly in Chapter 1, there can only be 'interactions' between sources and receptors if they are sufficiently physically co-incident for the effects of one activity to be measurably detected by the other. As sub-sets of this basic premise:

1. Is there a temporal component to physical co-incidence – does it occur rarely or regularly, or seasonally, for example
2. Does physical co-incidence occur on a two or three dimensional basis – if fish swim over or under an item and experience no effect, then the fact that they are physically co-incident in plan view is moot
3. Is it possible to quantify the degree of physical co-incidence, when assessing its overall effect? The issue here is not about absolute numbers, but is about the percentage of all of Scotland's migratory salmonids (and sub-sets of these such as seasonal stock components) that may be physically co-incident with devices
4. Is it possible to assess the degree to which an effect of an interaction, arising due to physical co-incidence, is harmful / negative / detrimental – i.e. to what degree does an actual interaction event possibly lead to a (likely significant) effect on a designated European site?

This consideration leads to a two-stage approach to Chapter 4:

1. An overview of knowledge about salmonid migratory and swimming behaviour in relation to the PFOW area
2. An overview of knowledge about types of interactions that can or could occur, and their consequences, if physical co-incidence is established.

4.2 Migration and Swimming Behaviour

4.2.1 Knowledge about Atlantic salmon Migration Pathways

The view that many of Scotland's Atlantic salmon migrate through the PFOW appears to be widely held, but it is important to assess the basis for this view. Malcolm *et al*, 2010 reviewed the historic and other information on salmon migration to and from Scottish waters, and concluded that:

- "*The information presented provides insights which may be useful for assessing the relative risk of renewables projects in particular areas of Scotland. However, the resolution of the available data and the risks of transferring findings between locations must be recognised as major limitations of current knowledge. In order to assess the potential impact of specific developments additional detailed local information on fish migration and behaviour, and the nature and location of the developments, would be required as identified in [ ] above. It should be recognised that obtaining these data will not always be technologically or logistically possible depending on location and the spatial precision required*
- *Finally, this report has been restricted to consideration of migratory routes and behaviour of salmon, sea trout and eels. Understanding of these aspects informs assessment of potential risks of development in particular areas and in some circumstances may be overwhelmingly important (i.e. where areas can be demonstrated to be unimportant for migratory fish). However, only in the case of negative interactions between the technology deployed and the migratory fish will the potential risks be manifested in impacts. It was not in the remit of this report to identify potential impacts of different renewable technologies, but it should be recognised that an understanding of migratory routes and behaviour is only half of the information required to assess impacts through an Environmental Impact Assessment (EIA) process."*

Knowledge gaps and further research are considered in Chapter 5 of this report, and possible modes of interaction between wave or tidal energy projects and migratory salmonids, if they are physically co-incident, are considered in 4.3.

Despite the cautious nature of the quotations included above, the review of Malcolm *et al* does provide a lot of useful information, including details of research undertaken on salmon swimming preferences (such as depth) and migratory behaviour in other countries. Some additional sources of information and headline findings include:

1. Mork *et al* (2012)[45] simulated the migration of post-smolt Atlantic salmon during their first four months at sea in the Northeast Atlantic using an individual-based model that combined a particle-tracking scheme with growth and behaviour routines, and concluded that both passive pelagic drift and active horizontal swimming behaviour are relevant. They indicated a preference for water with higher temperature and salinity, which displaced northward

[45] http://icesjms.oxfordjournals.org/content/69/9/1616.abstract

migration more offshore, away from the coastal area. (See also the discussion about the current Environmental Research Institute (ERI) project, Chapter 5)

2. Thorstad *et al* (2012)[46] pointed out that smolts and post-smolts swim actively and fast during migration, but in areas with strong currents, their own movements may be overridden by current-induced transport. Estuaries and river mouths are the sites of the highest mortalities, with predation being a common cause, and total mortality reported during early marine migration (up to 5-230 km from the river mouths) in the studies available to date varied between 8 and 71%
3. An earlier study in Canada by Lacroix and McCurdy (1996)[47] using tagged salmon smolts indicated that post-smolt movement was indicative of active, directed swimming with a reliance on ebb-tide transport for migration through a coastal area with strong tidal currents.

The challenge for the PFOW area is that all the research conducted and reviewed to date provides some interesting contextual information, but does not provide a complete answer to the question of likely physical co-incidence at a project specific level (further discussed below under 'salmon swimming behaviour'). Current research to address these issues is discussed in Chapter 5.

Some of the stakeholders consulted during the preparation of this DP expressed some surprise that local statutory (District Salmon Fishery Boards - DSFB) or non-statutory (e.g. Orkney Trout Fisherman's Association) groups did not have a more comprehensive database concerning salmonids in adjacent coastal waters. In response to this, the Association of Salmon Fishery Boards (ASFB) has indicated that this is unrealistic, since high quality freshwater fisheries management does not ordinarily involve detailed (and difficult to acquire) knowledge about fish in the marine environment. Recognising this, the workshop discussed whether there are any as-yet untapped or unrecognized sources of additional information which could be utilised by developers and regulators, but came to the conclusion that there were unlikely to be any significant sources of information.

Anecdotally, there are salmon quite close to the shores of the Orkney Islands[48], and presumably these are migrating past on their way to natal spawning rivers on the mainland of Scotland. There is generally no way of substantiating such anecdotes, or of assessing numbers involved. Bearing in mind the wide ranging nature of salmon, it would be most surprising if there were not at least some salmon found in Orkney and Shetland waters. On the other hand, one of the projects at EMEC in Orkney reported observing <u>no salmonids</u> during experiments over quite long time periods.

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[46] http://www.ncbi.nlm.nih.gov/pubmed/22803722
[47] http://www.mendeley.com/catalog/migratory-behaviour-post-smolt-atlantic-salmon-during-initial-stages-seaward-migration-2/
[48] Noted in MeyGen ES Technical Report – reference in Section 4.

It is difficult to make any judgements based on unofficial anecdotes, and as noted earlier, it may not "be technologically or logistically possible" to do very much in an area that is not even covered by MSS catch data. This will have to be taken into account by regulatory decision-makers. The wave and tide energy projects located off the western and northern Orkney coastline are not located in the narrow section of the Pentland Firth itself, and it ***may*** be that the level of 'risk' associated with these projects is less than those closer to the Scottish mainland or the narrows of the Firth.

4.2.2 Salmon Swimming Behaviour

Reiterating the point that interactions can only occur if the fish and the relevant equipment (or its effects) are physically co-incident, there are two aspects of interest to this study: where the salmon are located geographically; and where they are located vertically in the water column. Tidal energy turbines are typically located in water with sufficient depth that the top of the turbine blades are still several meters (5+) below the surface of the sea (see Chapter 2). If migratory salmonids – at whatever life stage – tend to prefer swimming at or near the surface, and this behaviour persists in the local situation, then there is much less chance of physical co-incidence.

This topic – swimming behaviour in terms of depth preference – is still a matter for further research (see Malcolm *et al*, 2010 and Chapter 5). There is some evidence from Norway that smolts do prefer to swim near the surface, but this evidence was largely gained in trials undertaken in fjordic conditions. What happens when smolts enter the open sea and commence their migrations to distant feeding grounds was not part of the research. Malcolm *et al* refer to adult salmon swimming near the surface, but making dives to great depths from time to time.

4.3 Interactions

4.3.1 Introduction to Interactions

The EIA process focuses on 'nature, scale and location' of proposed developments[49]. In the specific case of wave and tidal energy projects:

- **Nature:** of the proposed development is important because it might give an indication of the specific type of interaction that could occur – and these might not all be identical between wave and tidal devices

[49] See for example: http://www.snh.org.uk/pdfs/publications/heritagemanagement/eia.pdf

- **Scale:** of the proposed development is clearly an important issue. The larger the size or number of devices deployed, the larger the opportunity for physical (or similar) interaction in absolute terms
- **Location:** of the proposed development may be important in geographical terms. Hypothetically, for example, the location of a project may mean that there is more or less chance of a mobile species occurring there and / or being able to avoid it should their mode of behaviour allow such choices. Another consideration would be its immediate proximity to (in this case) a specific salmon river or fishery. Location of a proposed development is also of potential importance if it happens to be on or near an established, significant scale, migratory pathway for mobile species.

Table 9 provides a summary of the potential key effects on fish that could result from developing wave and tidal power around Scotland, as identified in the Scottish Government's Strategic Environmental Assessment (SEA)[50].

Table 9. Possible Interactions.

Construction/Decommissioning	Operation
• Disturbance • Smothering • Increased suspended sediments and turbidity • Disturbance of contaminated sediments • Marine noise	• Collision risk • Barriers to movement • Marine noise • Substratum loss • Decrease in wave exposure • Decrease in water flow • Increased suspended sediments and turbidity • Contamination • Electro Magnetic Fields (EMF) from cables

Of these, the SEA found that salmonids were either not sensitive to, or the effect was "*not relevant*", in respect of smothering, change in suspended sediment, substratum loss, decrease in wave exposure, and decrease in water flow. Salmonids were, however, considered to have "low" sensitivity to marine noise (during construction) and were potentially capable of detecting an electric field from installed cables. The sensitivity of salmonids to increased turbidity, barriers to movement, collision risk, and contamination were considered unknown.

[50] http://www.scotland.gov.uk/Publications/2007/03/seawave

A complete review of scoping reports and scoping opinions for PFOW projects, together with UK and international ESs and SEAs where available, has been undertaken during this study and is referred to throughout the remaining sections of this report[51]. It is clear, however, that the amount of data on the effects of wave and tidal energy developments on salmonids is somewhat limited, and that this situation is not restricted to the UK – other regulatory regimes around the world are in a similar position and are therefore also having to find ways to approach licensing such projects.

The study's research and consultation leads to a view that the potential key effects that require to be considered are: **noise and vibration** (particularly during construction), **physical encounter or collision** (and to a lesser extent barriers to movement), and **EMF** during operation.

Subject to further results from ongoing research and consultation, the main interaction of concern to UK regulators and advisors is that of **physical encounter** between tidal devices and migratory salmonids (SNH, 2013, pers. comm. January). There is much less concern, or the risks are considered much lower, in relation to wave energy converters, EMF and Noise. The same applies to the potential effects during construction / installation. It should be noted that migratory salmonids stakeholders do not universally share these views about the balance of risk between different interaction types, and are concerned about all types of interaction.

Notwithstanding the above, the main potential interactions are further considered below, and the possible interactions were discussed at the workshop.

One key point, when looking at possible interactions, is the degree to which there is little information about whether migratory salmonids will be sufficiently physically co-incident for there to be *any* interaction. This lack of complete certainty (although there is some evidence) about fish swimming behaviour and preferences was highlighted in 4.2, and remains important. **If the fish are not there, the types of interaction discussed in this section would not occur.**

Literature reviewed for this section of the report is cited where appropriate in the following sub-sections, but it is important to refer to a recent 'overview report': Copping A *et al*., 2013. Environmental Effects of Marine Energy Development around the World for the OES Annex IV[52]. This paper provides a comprehensive summary of all the currently available information on environmental effects, gained from a variety of wave and tidal energy projects around the world. It draws heavily on the Tethys database[53], and it provides two informative Case Study sections:

- Interaction of Marine Animals with Turbine Blades; and

[51] If required, it can be made available as an Addendum Report.
[52] http://mhk.pnnl.gov/wiki/images/4/42/Final_Annex_IV_Report_2013.pdf
[53] http://mhk.pnnl.gov/wiki/index.php/Tethys_Home

- Effects of Acoustic Output from Tidal and Wave Devices on Marine Animals.

4.3.2 Noise

4.3.2.1 Context

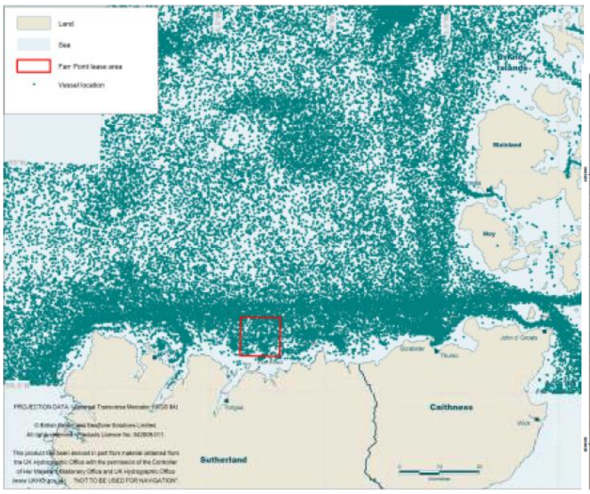
Copping et al (2013) define noise: "*The term noise is often used colloquially to describe unwanted sound, or sound that interferes with detection of any other sound that is of interest. However, noise is also used to describe background levels of sound in the sea, including the naturally occurring and spatially uniform sounds generated by distributed biological sources, weather events, or physical phenomena like ice ridging, some of which cannot be assigned to individual sources.*" The authors go on to discuss acute effects of noise, which might result in death or physical injury to animals, and chronic effects of noise, which might result in behavioural changes. Acute noises may come from one-off 'loud' events such as construction operations, whereas chronic noise might emanate from routine operations as well as (possibly) one-off events.

They also introduce the concepts of cumulative effects and in-combination effects of noise, and distinguish between the two – although they also point out that the US National Environmental Policy Act (NEPA) analyses consider both types and collectively refer to them as **cumulative impacts** (as is also the increasing tendency in the UK).

4.3.2.2 Baseline

The PFOW area is a busy area for shipping[54], which has implications for noise and physical interaction, as illustrated in Figures 9 and 10 below showing the level of fishing activity in the area (AIS data – fishing vessels over 300 tonnes, and VMS data – fitted to all UK vessels over 15m in length). Actual use of the area is likely to be much higher, particularly as a substantial proportion of the fishing fleet use vessels under 10m in length and the majority of recreational traffic is not included. The area is also acknowledged to have a high ambient underwater noise level, largely as a result of the high energy water movements taking place. As monitored, these noise levels are the baseline in terms of current salmonid migratory trends. Background noise levels in the Inner Sound, for example, are variable, lying in the range 106 – 139 dB re 1 µPa.

[54] http://www.scotland.gov.uk/Publications/2012/12/1868/7



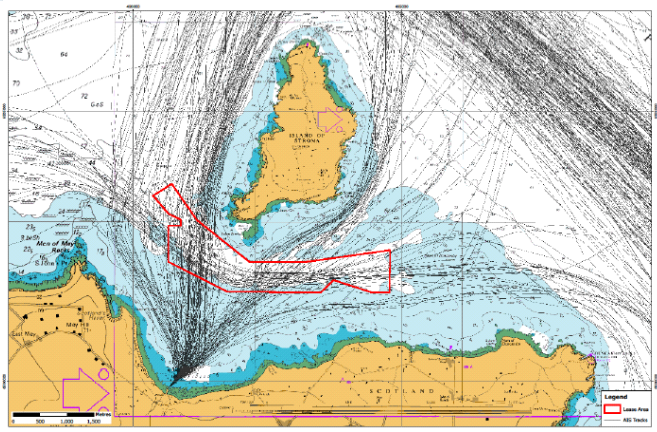


Figure 9. VMF Data[55]

Figure 10. AIS Survey data[56]

The degree of anthropogenic sound input to the area is potentially important: salmonids migrating through the PFOW area have been exposed to these on-going (and generally unregulated) pressures for many years. However, it should also be noted that the effect of such pressures on salmonid fish has not been studied.

4.3.2.3 Current Understanding

Summarising some of the findings from various studies:

1. The Kongesberg study for the MeyGen ES[57] provided some information about noise from different types of activity: "*The broadband source level for vessel noise is considered as 172dB re 1 µPa at 1m based on a tug vessel being the noisiest vessel being used during installation operations. Analysis of published drilling noise measurements indicates that a broadband source level of 144dB re 1 µPa at 1m is considered representative for the activities at the Inner Sound site*".
2. Scottish Executive SEA[58] - Marine Current Turbines (MCT) tidal current generator near Lynmouth in the Bristol Channel (Parvin, *et al*. 2005) concluded that effective source level of 166 dB re 1µPa at 1 m
3. Admiralty Inlet Pilot Tidal Project [59]: Reference to various studies concluded that Atlantic salmon can typically detect sounds between 95 and 130 dB (re 1µPa), at frequencies

[55] Pelamis Wave Power, April 2011, Farr point Wave Farm Development, Request for Scoping Opinion – Appendix 1, Preliminary Hazard Analysis.
[56] MeyGen, May 2011, MeyGen Phase 1 EIA Scoping Document, Appendix B – Preliminary Hazard Analysis
[57] http://www.meygen.com/the-company/reports-and-documents/
[58] Scottish Executive, March 2007, Scottish Marine Renewables SEA – Environmental Report, prepared by Faber Maunsel and Metoc PLC
[59] Public Utility No.1 of Snohomish County, 29 February 2012, Admiralty Inlet Pilot Tidal Projects (Project No. 12690) – Application for a New Pilot Project Licence (Minor Water Power Project) - Environmental Report, Everett, Washington.

between 30 and 400 Hz, and that given the greatest sound intensities that would be produced by the proposed project during construction / installation, operation, and maintenance would likely be less than 130-160 dB (re 1 µPa), and that adverse effects on fish are typically not seen at levels below 160 dB, it was not expected that fish in the project area would be adversely affected by underwater noise associated with the project.

4. The Modelling Techniques For Underwater Noise Generated By Tidal Turbines In Shallow Waters[60] study suggested that noise energy at 20 m from a 'typical' tidal turbine is some 119 dB re 1 µPa.
5. Modelling undertaken in support of the Scottish Government's SEA (op cit) on Scottish Marine Renewables concluded that the relative noise levels associated with arrays of up to 50 devices, with separation distances of in excess of 50m, increased by less than 3db compared to the noise level of a single device.
6. The Infrasound Mini-Review[61] describes an experimental design using low frequency sounds which were found to be effective in discouraging fish movements – up to a distance of 3 m. The implication is that whilst noise can have an effect on fish, and whilst some noise can propagate over long distances in water, the measureable effect of deterring fish passage is limited to a field quite close to the sound source
7. The Effects of Tidal Turbine Noise on Fish Hearing and Tissues[62] report concludes that "*Collectively this means that Chinook salmon may be at a relatively low risk of injury from tidal turbines located in or near their migration path*."
8. In Cobscook Bay[63], research found that the noise from the proposed development met regulatory standards for fish hearing shift and allowed the regulators to lift a restriction on pile driving during periods when Atlantic salmon smolts may migrate through Cobscook Bay (April 10 to November 7)
9. The SNH Report[64] on EMF and noise generally concludes that there are many knowledge gaps, but makes the statement: "*For noise, the construction phase appears to be the most critical time because of the acute effects. The type of construction, including the time-scale over which it is carried out, will play an important role in any impacts on the species under investigation. From this review, it would be suggested that fish that receive high intensity sound pressures (often in close proximity to the MRE) may be harmed to some degree, whereas those at distances of 100s to 1000s of metres may exhibit behaviour responses which will be dependent on the received sound*".

[60] http://eprints.soton.ac.uk/192959/1/EWTEC2011_Lloyd_Final_Draft_Comments.pdf
[61] http://mit.biology.au.dk/images/Infrasound%20minireview.pdf
[62] http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20786.pdf
[63] http://mhk.pnnl.gov/wiki/index.php/Cobscook_Bay_Tidal_Energy_Project.
[64] http://www.snh.org.uk/pdfs/publications/commissioned_reports/401.pdf

The other main imponderable is the behaviour of a salmonid if it does encounter a level of noise that would tend to deter it from progressing further. Does it turn around and return to its original point of origin, or does it make repeated attempts to progress, taking slightly different routes? Can it turn round at all, or will it instead be quickly forced through the unfavourable region because it is entrained on a current that is much faster than its swimming speed? Although there is nothing to back up the assumption other than known facts about (for example) smolt swimming speeds and the prevailing current speeds in part of the PFOW area, the general view is that post-smolts travelling west through the narrower parts of the Firth are being 'transported through' with the currents when they are in the right direction – and that their behaviour is predicated on this strategy.

4.3.2.4 Summary – Noise

1. The DP concurs with the general view that there are still some knowledge gaps relating to possible noise impacts on migratory salmonids from wave or tidal energy developments in the PFOW area
2. However, there is some evidence from the literature that any effects on behaviour that would be sufficient to deter passage are likely to be limited to regions close to the source of the noise
3. Operational noise appears to be less of a significant issue than construction noise, but there is also some evidence that the nature of wave and tidal energy construction operations (specifically the type of piling, being less impulsive, etc. than other types of development, and construction will be relatively short due to the small-scale of the first phase projects) has not caused major regulatory concern in other jurisdictions
4. It is also important to stress the construction techniques which are likely to be prevalent in the PFOW area, i.e. pile drilling as opposed to pile driving.

4.3.3 Electrical and Magnetic Fields (EMF)

4.3.3.1 Context

The Tethys website[65] introduces the context for EMF succinctly: "*When electricity is generated at sea, it must be transported back to an onshore electrical grid. As electricity is transmitted through cables back to shore, electromagnetic fields are created. Although the electrical field is damped quickly in seawater, the magnetic field persists and may induce an electrical field. While the earth has a naturally occurring static geomagnetic field generated by tidal motion, additional EMF signals from offshore renewable energy devices may have effects on certain marine organisms such as elasmobranchs (sharks, skates and rays), finfish including sturgeon, eels, and sea turtles. Due to the fact that these organisms use the earth's magnetic field for orientation, navigation and hunting, additional sources of EMF can affect reproductive success, migratory patterns, or even cause mortality*."

The importance of magnetic fields as an aide to salmon navigation is noted[66].

It is possibly helpful to discuss what EMF means – the acronym covers different things. The following diagram illustrates our appreciation of what the term means – Figure 11.

[65] http://mhk.pnnl.gov/wiki/index.php/EMF

[66] http://www.sciencedaily.com/releases/2013/02/130207131713.htm - with acknowledgement that this is not a peer-reviewed document. It does however refer to a recent published study, and provides a useful overview.

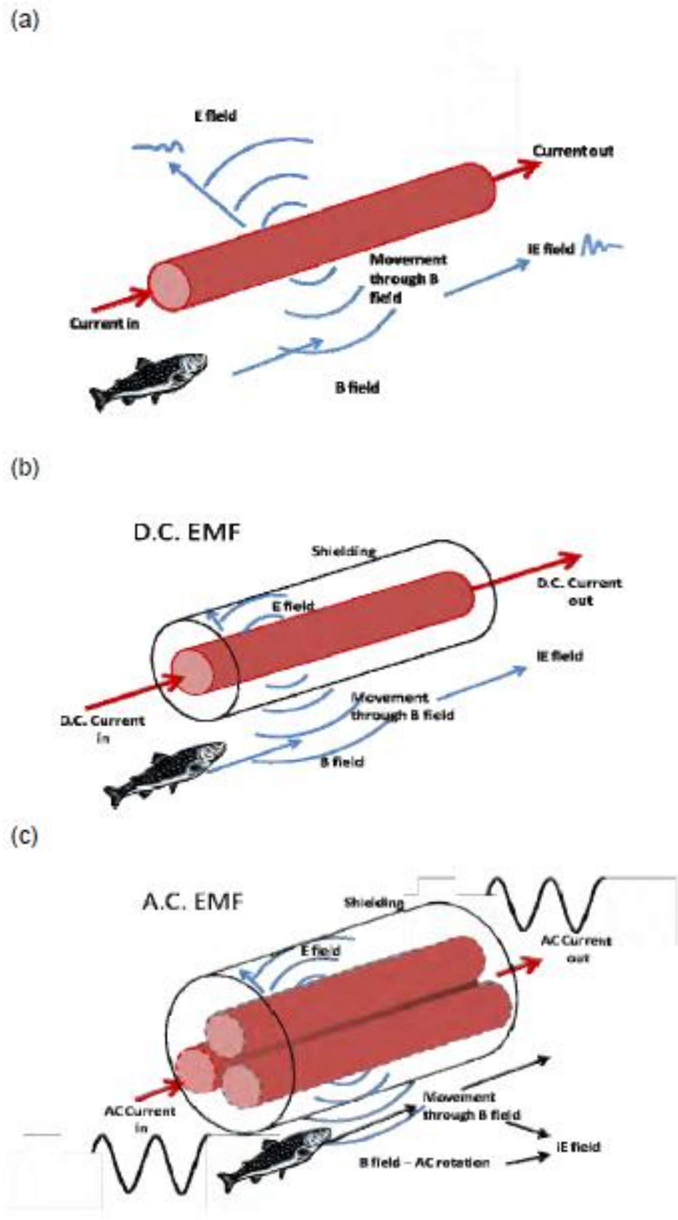


Figure 1. The electric and magnetic fields associated with a subsea cable. (a) A schematic diagram of the EMFs associated with an unshielded cable. For electric (E) and induced electric (iE) fields, wave magnitudes indicate relative sizes of EMF with distance from the cable. (b) an HVDC cable showing the shielding that contains the direct E field. The iE field is induced in the fish as it moves through the B field. iE fields are also induced by water moving through the B field. (c) an HVAC cable showing the three cores with the alternating current following a typical sine wave back and forth through each core. Similar to the DC cable iE fields are induced by the water and/or fish movement. Furthermore, the out of phase magnetic field emitted by each core causes a rotation in the magnetic emission which induces an iE field in the surrounding water.

Figure11. A diagrammatic representation of different aspects of EMF. Source: SNH

4.3.3.2 Baseline

It is clear that other anthropogenic sources of electric and magnetic fields have been present in the marine environment for many years[67], including subsea telecommunications and power cables. The interactive map system offered by the KIS-Orca website[68] illustrates where some of these cables lie in relation to the PFOW area – and highlights that two power and two telecommunication cables run straight across the base of the Pentland Firth, from Thurso in the south, to Orkney or beyond in the north. Figure 12 identifies the routes of these. As with shipping noise, it is worthwhile stressing that no specific studies have been undertaken in relation to the possible effects of these long-established subsea cables on migratory salmonids.

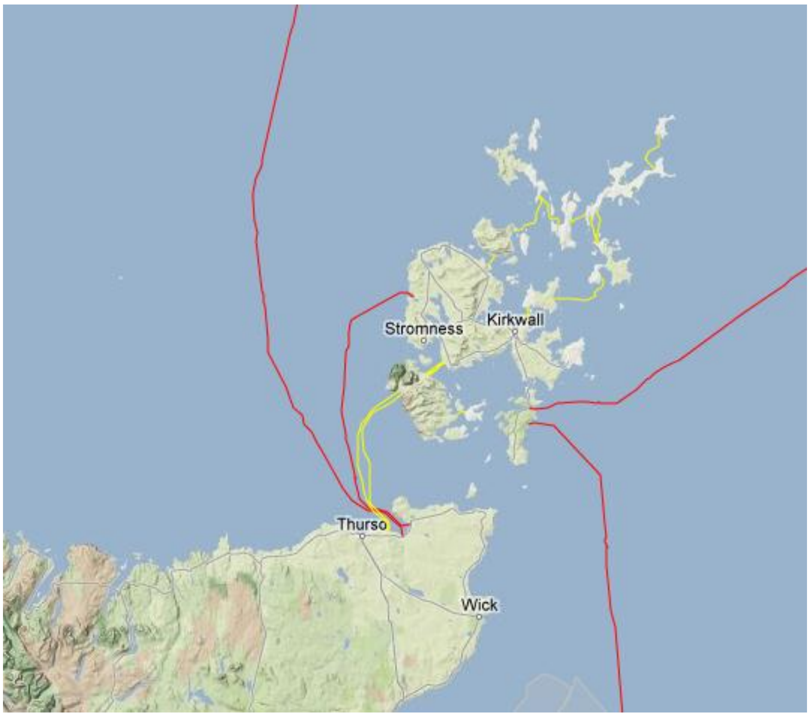


Figure 12. Power (yellow) and communications cables (red) that currently cross the Pentland Firth.

4.3.3.3 Current Understanding

The possibility of interactions between migratory salmonids and electrical (induced) or magnetic fields is recognised. The available state of knowledge is well summarised in the SNH Review (op cit), and in other documents such as the MeyGen ES.

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[67] http://mhk.pnnl.gov/wiki/images/e/e1/The_Potential_Effects_of_Electromagnetic_Fields_Generated_by_Sub_Sea_Power_Cables.pdf

[68] http://www.kis-orca.eu/map#.UUDNV1dOyLV

This study has not been able to discover any new information on this subject, but as a result of examining the existing literature, and as a result of the consultations held as part of the research, the following observations are offered in the summary below.

4.3.3.4 Summary – EMF

1. The DP concurs that there are outstanding knowledge gaps
2. There is ongoing research work in this area (e.g. MSS tank tests), and results are expected soon
3. The EMF effects dissipate very rapidly in water[69]
4. The issue of fish behaviour and preference is relevant again: fish near the surface of the sea are unlikely to be physically co-incident with any strong EMF, depending on the technology in question, and the ability to bury/shield cables.

4.3.4 Encounter Risks

4.3.4.1 Context

The DP has already indicated the relatively widely-held view that, subject to further results from ongoing research, the main interaction of concern to regulators and advisors remains 'physical encounter' or 'collision' between, mainly tidal energy equipment, and migrating salmonids.

It is also important to stress that 'physical encounter' does not just cover the possibility of a fish striking a moving turbine blade itself, but also covers the concept that fish might be impacted through contact with the areas of high energy water associated with the rotating turbine blades.

Wave Energy Equipment

Wave energy devices are fundamentally different to tidal turbines, and whilst there might be some concerns about the 'barrier to migration' effect of near-surface swimming salmonids from such devices if they are encountered sideways-on to a migratory pathway, physical damage to fish has apparently in most cases been 'scoped-out' of further detailed assessments.

Furthermore, the locations of the wave energy sites in the PFOW area are generally seen as more remote from 'pinch points' such as the narrows of the Pentland Firth – with a consequently lower

[69] See ES Summaries – Wave Hub, Admiralty Inlet Pilot Tidal Project, and Scot Exec SEA.

chance of the equipment being physically co-incident with large concentrations of migratory salmonids. The Farr Point site has come under more scrutiny than the other wave energy locations, largely because:

- It is the only wave energy site near the Scottish mainland
- Whilst likely to be located some distance from the shore, in relatively open water, it is located opposite the mouth of at least two salmon (and pearl mussel) SACs – the River Naver SAC and the River Borgie SAC.

Tidal Energy Equipment

There is a perception that the rotating blades of tidal energy turbines provide the greatest degree of risk, if migratory salmonids are physically co-incident with the equipment, due to the possibility of physical injury and / or death.

The blade ‘tip speed’ for a tidal turbine is significantly less than an equivalently rated onshore wind turbine: in the order of between 14m/s to 21m/s (max) for tidal turbines compared to up to 70m/s for wind turbines (primarily due to the shorter blade length of tidal turbines). The two situations cannot of course be directly compared - water and air are very different media.

4.3.4.2 Baseline

It is difficult to hypothesise what the baseline situation is, except to state that:

1. Migratory salmonids in the PFOW area have had to contend with the chance of encountering the screws of vessels in the area for many years – although these vessels are generally mobile within the area, and the screws are generally to be encountered nearer the surface of the water than would be the case with tidal energy devices. The location of the screws at the back of vessels offers a high degree of protection.
2. In addition, migratory salmonids in the PFOW area have also had to contend with a range of other activities, such as ports and harbour works and the laying of earlier subsea cabling – although the degree to which these have had an impact has not been studied
3. Apart from the devices present at EMEC in recent years, migratory salmonids in the PFOW area have not had to encounter fixed-location moving blades of the type relevant to tidal energy devices.

4.3.4.3 Current Understanding

The risk of migratory salmonids being damaged by physical contact with the moving blades or the high energy moving water regions of a tidal energy device has been and remains the source of a significant volume of both grey and peer-reviewed literature. Issues such as blade speed, blade size, blade height, blade shrouding, location and, critically of course, whether or not there will be salmonids present are all relevant to the debate. Opinions differ between commentators and it would not be productive to repeat all of these within this study. A comprehensive list of references is offered as part of this report[70]. One recent study[71] provides a summary of three relevant and recent pieces of work:

1. **Video monitoring of OpenHydro's 6 m diameter turbine at EMEC.** The OpenHydro device, installed at EMEC (in Orkney waters), shows no evidence of any salmonid species near the turbine during relatively long periods of observation. (However information on the use of the site by salmonid species is lacking). Information is presented about the apparent behaviour of pollock near the turbine, and no damage to the fish is reported. These fish could be locally resident in the area and have been able to familiarise themselves with the installation.
2. **EPRI entrainment and survival study in a flume tank.** The EPRI experiments are relevant, because they included testing Atlantic salmon smolts, and in another experiment, rainbow trout[72]. The overall results were interesting, with passage survival rates generally above 90% (>99% for rainbow trout). The experiments concluded that the likelihood of mortality occurring were linked to velocity of fish relative to the blade edge and fish size, with greater speed and fish size increasing the chance of mortality. It is important to stress that these results are for turbine designs that are different to those proposed for the PFOW area tidal energy devices. One consultee to this study has pointed out that 90% survival implies that 10% of all fish meeting the system tested did not survive, and this is an important consideration. On the other hand, these tests were in a tank and therefore fish interactions were 'forced' / far more certain. It should be noted that the fish in these trials were much smaller than adult salmon and velocity of fish relative to the blade edge was less, with both these factors likely to reduce mortality in the tank trials
3. **Hydro Green Energy, LLC entrainment and survival study in the Mississippi River**. The Hydro Green turbines were horizontal axis, albeit ducted. Summarising the conclusions in the extract shown here as Figure 13.

[70] http://mhk.pnnl.gov/wiki/index.php/Tethys_Home; http://www.un.org/Depts/los/consultative_process/icp13_presentations-abstracts/2012_icp_presentation_attrill.pdf; http://www.gracelinks.org/blog/947/tidal-power-rolls-in;

http://mhk.pnnl.gov/wiki/images/c/cb/Evaluation_of_Fish_Injury_and_Mortality_Associated_with_Hydrokinetic_Turbines.pdf

[71] http://www.snopud.com/Site/Content/Documents/tidal/ai_final/FLA_Volume_II.pdf

[72] http://mhk.pnnl.gov/wiki/images/c/cb/Evaluation_of_Fish_Injury_and_Mortality_Associated_with_Hydrokinetic_Turbines.pdf

turbulent waters or sudden appearance of fully inflated tags). Researchers noted that many factors that may impair a fish's ability to avoid predators (e.g., stress, loss of equilibrium) are not an issue with the hydrokinetic turbine evaluated, because pressure changes, severe turbulence, shear stress, and cavitation do not occur. Researchers concluded that because survival was 99 percent, and there was no indication that fish were injured upon passing the through the hydrokinetic turbine, the units should have little if any effect on entrained fish (Normandeau 2009, Hydro Green Energy 2010*a*). FERC acknowledged these findings in a letter issued March 3, 2010 and stated that the report fulfilled the study requirements.

Figure 13. Extract from Hydro Green study.

4. In Cobscook Bay (Maine)[73], "*acoustic cameras clearly show evidence of fish approaching the turbine and a certain proportion turning away from the turbine to swim back towards their origin or to pass above or below the turbine on their original track; few fish (most notably smaller fish) pass through the turbine-swept area. Fish were almost always present in the wake of the device, when it was present. No fish were seen to be struck or suffer damage from passing through the turbine, but the windows of observation were relatively short in comparison to the life of an operating turbine. In addition, the researchers were not able to observe the fish after they left the vicinity of the turbine or to assess any long-term effects of passing through the turbine*".

One of the main issues when considering encounter risks is the 'geometry' of the environment. In essence, the physical mass of the tidal energy devices, individually or collectively, only represents a small percentage of the volume or cross-sectional area that salmonids might be migrating through. That occupancy level might be perceived to be higher or lower in different parts of the area, but it is an important consideration and a potential basis for a modelling approach.

Modelling Encounter Risk

Encounter models have been used extensively in ecology to estimate predator-prey interactions of marine animals and to assess risk of predation mortality[74]. As part of the ongoing 7th Framework Equimar Project, the Scottish Association for Marine Science (SAMS) is developing a series of encounter (long range) and evasion (close range) models to determine underwater collision risks for large fish, mammals and birds with marine renewable devices[75]. Reference has already been made to the MeyGen ES that has been published[76]. One of its key supporting documents is the technical

[73] http://mhk.pnnl.gov/wiki/index.php/Cobscook_Bay_Tidal_Energy_Project.
[74] See for example: http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/bird-collision-risks-guidance/
[75] http://www.samsrsl.co.uk/renewable-energy/marine-mammals/collision-risk
[76] http://www.meygen.com/the-company/reports-and-documents/

paper on modelling. It sets out a modelling approach to assessing the number of salmon – either smolts or adults – that might encounter the turbine blades during the two different phases of development in the Inner Sound of the Pentland Firth.

One cautionary note to modelling, on the positive or negative side, is that fish might or might not behave predictably or be distributed uniformly within the volume or area being modelled. For example:

1. The fish might be somehow attracted to the device/s (e.g. turbine), thus increasing their encounter rate
2. The fish might detect the device at some distance, and be able to avoid it
3. The fish might favour a small part of the modelled area: a preference for swimming in the top 6 m of the water column would reduce encounter rates to almost zero in most cases, for example.

A range of assumptions underpin the MeyGen model, but the methodology appears to be useful – although some of the assumptions could be debated (see below). There are several 'ranges' within the model, but the model's outcomes broadly show a relatively low number of potential interactions between the tidal turbines and migratory salmon smolts and adults.

Some public sector bodies have responded favourably to both the approach and effort that has gone into the technical report modelling[77], and a cross-check analysis undertaken by the study team on estimates of the number of fish which could migrate through the Pentland Firth (specifically smolts) using an alternative method[78] came up with a number very similar to the one in the technical report. Some of the other assumptions of the models are currently being given careful consideration by the public sector bodies.

The technical report has attracted some comments[79], one of which states it may be unreasonable to assume that the migrating salmon and smolts use the full area/volume of the Pentland Firth narrows, and that they might alternatively tend to favour migrating through the very narrow Inner Sound, hugging the coast. Figure 14 illustrates the geography, and the two main cross sections (Inner and Outer Sound) used within the model.

[77] Pers comm. SNH and MSS, 2013
[78] An alternative approach to 'wetted area' is to choose a river (the Tweed in this case), examine recent catch records, make an assumption about exploitation rate, make an assumption of total marine mortality – and thus arrive at a theoretical number of smolts that might leave the river in one year.
[79] See for example: http://www.asfb.org.uk/wp-content/uploads/2011/04/ASFB-response-to-Mey-Gen-Application.pdf

Figure 14. The assumed area of the Inner and Outer Sound, used in the ES model. Source: MeyGen.

The assumptions that the entire Inner and Outer Sound might or might not be available for smolt or adult migration are of course susceptible to challenge, but the tidal current images shown in Figure 3 are interesting. Intuitively they would perhaps suggest to the layman that smolts, which are being carried on currents, when the current speed exceeds the smolts' swimming capability, are rather **more likely to be entrained into the full Outer Sound** than the Inner Sound, when the flows are in a westerly direction. It is likely that more information about this will become available in mid-2013, as The Crown Estate-funded ERI project on particle / biological modelling concludes (see Chapter 5).

On balance the model presented in the MeyGen Technical Report is a very good start to the development of techniques to assist regulators and others during the process of risk assessment and allows the impact of varying some of the assumptions and input parameters to be investigated. This is particularly so considering that without the attempt to model it, the assessment / conclusions would likely be more uncertain.

4.3.4.4 Summary – Encounter Risk with Tidal Energy Devices

The broad outcomes from considerations in this DP about encounters with tidal arrays are:

- There is still a degree of uncertainty about both the chances of encounter on a numeric basis, and the outcomes of such encounters if they do occur
- The swimming behaviour, especially depth, remains an important risk-assessment question
- Modelling is a potentially useful tool, and should be developed.

4.3.5 Barriers to Migration

When considering migratory salmonids, barriers to migration are normally thought of in terms of physical structures within river systems: dams are the classic example.

In terms of wave or tidal energy developments, the term is introduced speculatively in relation to **wave** energy generating devices. The overall impression that wave devices pose less threat of serious impact to migratory salmonids is clear, as reported previously. The exact details of the swimming behaviour and preferences of migratory salmonids remains unclear – also as reported.

However, there is a hypothetical question: if salmon smolts (or adults) did prefer to swim in the top 6 m of the sea, what would they do if they encountered a wave energy device 'side on'?

Figure 16 provides a non-scaled illustration (from a plan view perspective) of how near-shore and offshore wave energy devices might be deployed, together with some descriptive text.

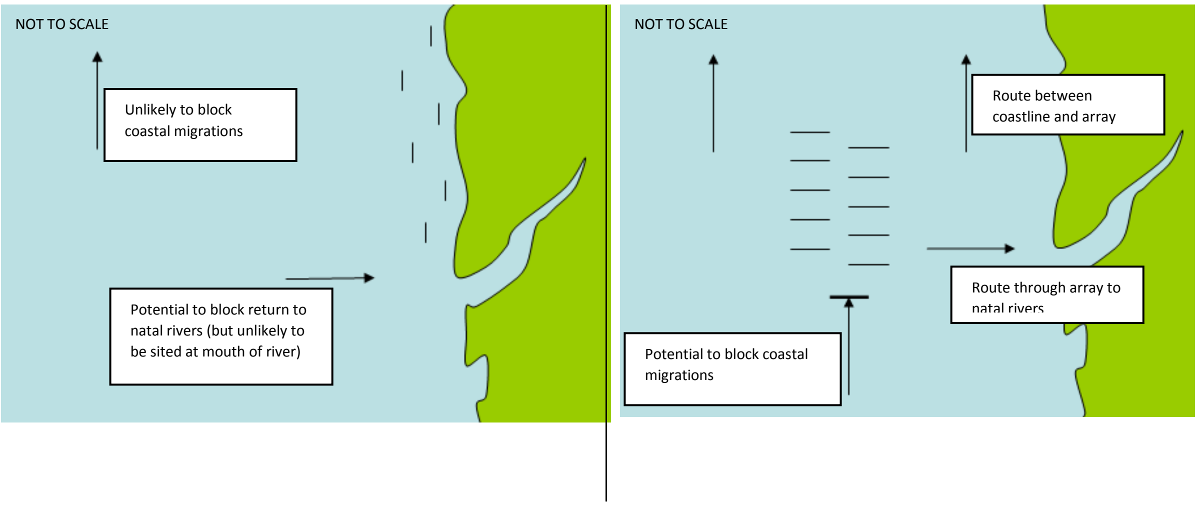

Figure 15. Plan view of possible deployment of (near shore and offshore) wave energy devices.

There is the theoretical potential for fish that swim near the surface to encounter an array of wave energy devices 'side on' – and if they continue in the same direction, meeting several devices oriented at right angles to their direction of travel.

As Figure 15 indicates, this study perceives the 'barrier' effect to be relatively low risk, for the following reasons:

1. Little is known about the swimming capability of fish that 'prefer' to swim near the surface (if indeed that is the case), but it seems improbable that they cannot choose to swim at different depths if circumstances dictate. It is known that adult fish make deep dives as a matter of normal behaviour
2. Offshore wave devices will be deployed at some distance from the shore – there is a wide migratory corridor either side of them and between them

3. Inshore devices would be very unlikely to be moored directly in front of the mouth of a salmon river or netting station – which is when a direct shoreward swimming direction might be taken
4. Deployments of first phases / arrays will only consist of a few devices, so there will be opportunities to observe what interactions, if any, occur.

Other studies report:

1. Lewis Wave Power ES[80] – "*The barrier to fish or shellfish passing through the site during the construction phase will be both small, relative to the available sea area, and temporary and that Salmon and sea trout are strong swimming, streamlined fish, easily capable navigation around any physical barrier that the installed infrastructure may present. As the majority of the devices will be within 700m of the coastline it is unlikely that any fish or shellfish species will be migrating in this direction as it is perpendicular to the shoreline and they would soon hit land. Furthermore individuals of most species will be able to navigate around the devices and pass through the spaces between the Oyster WECs*."
2. Environmental Report - Multiple Wave Energy Converter Project[81] -"*It is anticipated that this will have no adverse affect upon the fish themselves*."
3. Clarence Strait Tidal Energy Project, Northern Territory, Australia[82] - "*It is expected that species that can negotiate rapid currents are highly agile and will be readily able to avoid obstacles*."

4.4 Cumulative and In-Combination Effects

It is appropriate to acknowledge the need to assess the possible **likely significant effect** of either more than one wave and / or tidal development, and / or one or more of these in combination with other developments, on migratory salmonids.

All of these considerations are now properly articulated in the guidance on cumulative impact assessment (CIA) that has emerged from other recent work streams. In particular, a Discussion Paper and final project report on **Cumulative Impact Assessment in Pentland Firth and Orkney Waters** has been published by The Crown Estate (see http://www.thecrownestate.co.uk/energy-

[80] http://www.aquamarinepower.com/sites/resources/Reports/3172/Lewis%20Wave%20Power%2040MW%20Oyster%20Wave%20Array%20Environmental%20Statement.pdf
[81] http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/CXR-ARPAETechSupportAppendices.pdf
[82] www.nretas.**nt**.gov.au/__data/assets/pdf_file/.../noi_**clarence**.pdf

infrastructure/wave-and-tidal/pentland-firth-and-orkney-waters/enabling-actions/projects-and-publications).

It is not necessary / appropriate for this DP to make further comment on a parallel work stream – except to note that final recommendations from such work should be adopted with specific respect to the application and assessment process as it pertains to migratory salmonids and wave and tidal energy projects in the PFOW area.

4.5 Conclusion to Interactions

This section has highlighted a lack of detailed knowledge about some aspects of the key potential interactions between wave and tidal energy developments and migratory salmonids in the PFOW area, whilst at the same time it has presented some evidence about what is known in Scotland, and what has been discovered in other parts of the world. The key knowledge gaps, and current and future research to address them, are discussed in Chapter 5.

The authors have distilled a view, based upon the reviews conducted, that possible interactions between PFOW wave and tidal energy projects and migratory salmonids (and their potential significance) are perhaps not as daunting as the authors might first have imagined. Some of the research cited, whilst not providing incontrovertible evidence, has given some potential comfort in terms of possible likely 'significant' effects on migratory salmonids in Scotland from the wave and tidal energy projects that are currently under consideration.

5 KNOWLEDGE GAPS AND RESEARCH

5.1 Introduction

It is worth emphasising what underpins the licensing approach to the Habitats Directive with respect to proposed wave and tidal energy projects in the PFOW area, when it comes to taking into account the integrity of 17 designated European sites. The approach is:

1. Understand, as well as possible, the baseline situation before any deployment takes place
2. Some initial Phase I deployments are small-scale to start with, thus mitigating risk at a population level to the European sites
3. Observe (in an appropriate and proportionate way) the effects of the initial small scale deployments
4. On the basis of that 'observation', obtain the evidence to put forward a scientifically justified case that future licensing decisions will also not lead to a 'likely significant effect' on the European sites.

There appears to be some sensitivity amongst a range of stakeholders about the terminology relating to the acquisition of further knowledge, with the word 'monitoring' being viewed with caution. The Scottish Government's own EIA and HRA guidance document appears to be relatively clear on this matter:

> *"6.1.2 Monitoring*
>
> *Monitoring is a non-statutory procedure but may be required by conditions on a project consent/licence. As the implementation of mitigating measures may still not guarantee their success in reducing environmental effects, it is vital that the effectiveness of mitigation is monitored to ensure that it meets the standards and achieves the objectives anticipated in the decision. Monitoring can provide information likely to be required for future mitigation of similar developments. It may also be necessary where there is no mitigation implemented.*
>
> *To ensure compliance the developer should incorporate consent/licence conditions into the project specific environmental monitoring programme (as previously described)."*

Whatever the terminology, the principle of the need to acquire new or <u>better</u> knowledge in order to constantly improve a baseline understanding is very clear. It may be more helpful to think of a matrix of existing knowledge appraisal and new knowledge acquisition: Figure 16. It should be noted that as long as a thorough overview of the key issues and knowledge gaps exists, the 'topics' that need to be considered do not tend to change – it is a matter of improving the state of knowledge with respect to each of them.

It is necessary to consider which components (or sub-sets) of the matrix in Figure 1 relate to project-specific requirements under the EIA and / or HRA process, and which relate to wider regional initiatives / research. The distinction is important in terms of who might be responsible for undertaking / funding different types of 'knowledge acquisition'.

It is also important to differentiate the need for knowledge acquisition, of any type, in relation to specific projects under consideration: is the requirement likely to be different between wave energy and tidal energy projects, or between projects located in one area as opposed to another? Of course this type of fundamental consideration applies to any sectoral regulatory process, not just wave and tidal energy.

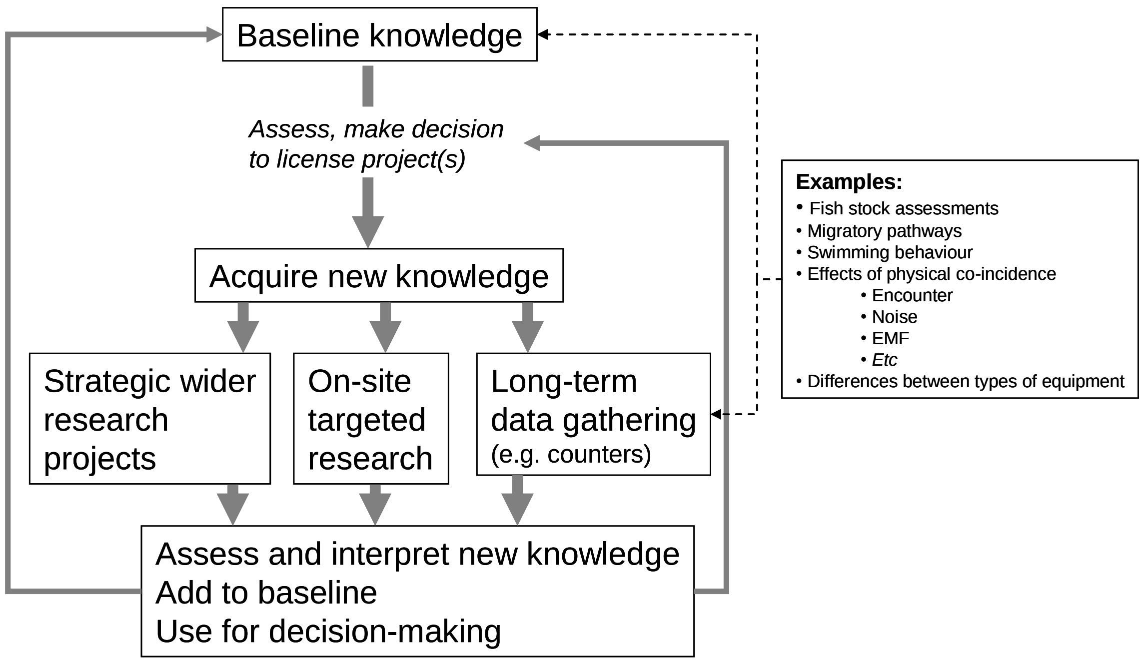

Figure 16. Acquisition of knowledge.

5.2 The Baseline in Scotland – Current Knowledge

Some concern may have arisen over the baseline assessment issues (step 1 in part 5.1). Atlantic salmon has been an important species for Scotland for generations, and under the statutory oversight of the DSFBs for more than 150 years. In addition, it has been a key focus of government funded research for decades. A lot should be known about salmon, and individual developers can only use what information is there, **or can reasonably be obtained**, in terms of existing baseline information when approaching the application and EIA process. However, developers might be able to helpfully contribute to wider strategic research, which might provide useful additional information about specific applications. The scoping request provides developers with details of baseline information which needs to be included. Figure 18 reproduces the generic request which has been used.

Figure 18. EIA Scoping Opinion.

Annex 6. Marine Scotland scoping comments in relation to information requirements on diadromous fish of freshwater fisheries interest

Offshore renewable developments have the potential to directly and indirectly impact diadromous fish of freshwater fisheries interest including Atlantic salmon, anadromous brown trout (sea trout) and European eel. These species use the coastal areas around Scotland for feeding and migration and are of high economic and / or conservation value. As such they should be considered during the EIA process. Developers should also note that offshore renewable projects have the potential to impact on fish populations at substantial distances from the development site.

In the case of Atlantic salmon information will be required to assess whether there is likely to be any significant effect of developments on rivers which are classified as Special Areas of Conservation (SAC's) for Atlantic salmon under the Habitats Directive. Where there is the potential for significant impact then sufficient information will be required to allow Marine Scotland to carry out an Appropriate Assessment.

In order that Marine Scotland is able to assess the potential impacts of marine renewable devices on diadromous fish and meet legislative requirements the developer should consider the site location (including proximity to sensitive areas), type of device, and the design of any array plus installation methodology. Specifically we request that developers provide information in the following areas:

1. Identify use of the proposed development area by diadromous fish (salmon, sea trout and eels)

a. Which species use the area? Is this for feeding or migration?

b. At what times of year are the areas used?

c. In the case of salmon and sea trout what is the origin / destination of fish using the area?

2. Identify the behaviour of fish in the area

a. What swimming depths do the fish utilise

b. Is there a tendency to swim on or offshore

3. Assess the potential impacts of deployed devices on diadromous fish during deployment, operation and decommissioning phases. Potential impacts could include:

a. Strike

b. Avoidance (including exclusion from particular rivers and subsequent impacts on local populations) *c. Disorientation that could potentially affect behaviour, susceptibility to predation or by-catch, or ability to locate normal feeding grounds or river of origin*

d. Delayed migration

4. Consider the potential for cumulative impacts if there are multiple deployments in an area.

5. Assess 1-4 above to determine likely risk.

a. If there are insufficient data to determine use of the development area, these should be obtained

b. If there are insufficient data on the origin / destination of fish using the area then these should be obtained

c. Where it is not possible to obtain site specific data, the developer should make a convincing argument why this is the case and apply appropriate expert judgement based on published information.

6. If there is any remaining doubt as to the potential impacts of a particular development, then the developer should recommend a scientifically robust monitoring strategy to assess any impacts either on stocks as a whole, or on particular rivers as necessary.

Marine Scotland Science has completed a review of migratory routes for Atlantic salmon, sea trout and eels relevant to Scotland. The review is available from http://www.scotland.gov.uk/Resource/Doc/295194/0111162.pdf. This will assist the developers in identifying what pre-existing information is available and what supplementary site specific data will be required.

MSS has explained to the study team that the generic scoping opinion was constructed as shown above because these are the issues that in general must be considered. This topic was discussed and explained more thoroughly during the workshop. The baseline for Atlantic salmon in Scotland is what MSS and DSFBs already know: catch statistics and their interpretation, counter history, and the many specific studies undertaken over the years (such as tagging experiments and similar). The question for developers is whether they can **reasonably** and **proportionally** be expected to add to the current baseline information through primary research during EIA – and whether each developer faces the same requirements, irrespective of equipment type and / or location. Some comprehensive guidance on this was a useful outcome from the workshop discussions.

The more detailed baseline on what is currently known or not known for certain about the **possible interactions** between wave and tidal energy devices and migratory salmonids has been considered in Chapter 4 of this report.

The remainder of Chapter 5 is devoted to summarising key knowledge gaps, and identifying how these are, and could be in the future, filled.

5.3 Knowledge Gaps

The key knowledge gaps have been touched-upon in Chapters 2 to 4, but it is worthwhile to bring them all together here in the current section of this report. The same exercise has just been completed by MSS, and this section of the report draws extensively upon that work.

Table 10. The main knowledge gaps

Atlantic Salmon – Behaviour and Migration
• There is no direct observational information on the behaviour (including swimming depths, speeds and near shore/offshore movement) of Atlantic salmon post-smolts in the Scottish context.
• There are currently little data on the migratory pathways or geographical distribution of post-smolts in the North Sea.
• It is uncertain whether adults or post-smolts migrate through the area around Orkney and Shetland or if the Pentland Firth is the preferred or only route used.
• There is uncertainty as to the mechanisms and routes by which adult salmonids home to and around the Scottish coast to the proximity of their natal rivers.
• There is limited information on the timing (seasonality) of migration for both juvenile and adult fish for specific locations on the Scottish coast.
Sea Trout – Behaviour and Migration
• There is currently no detailed information on post-smolt habitat use on the east coast of Scotland where the geography is significantly different from previous studies.
• In the case of both the east and west coast adult sea trout, there is very limited information on migration and feeding areas.
• There is currently little information on the swimming depths used by sea trout post-smolts or adults
• There is limited information on the timing of migration for both juvenile and adult fish for specific locations on the Scottish coast
Electro Magnetic Fields (EMF)
• There is need to develop baseline understanding of the impact of field strength electric and magnetic fields on fish.
• Benefits or otherwise of minimizing the number of cables running from devices to the shore
• Actual electric and magnetic fields generated from cables associated with wave and tidal device arrays (i.e. in combination effects)
Noise
• Direct effects on migratory salmonids: experimental studies of fish responses to vibrations or noise

generated by wave and / or tidal devices
• Radiated noise from arrays
Collision
• Escape option modelling
• Field-based monitoring studies of fish behaviour and mortality, in the vicinity of tidal power devices
• Modelling of collision risk – and implications of model outcomes, including possible close proximity (cavitation) effects

The need to assess risk and identify possibilities of significant negative impact is the main driver in regulatory decision-making, and on the basis of research and consultations undertaken as part of this study, it would appear that addressing four key 'knowledge gaps' would achieve the maximum benefit for all parties:

1. **Migratory pathways / behaviour** – to what extent are migratory salmonids likely to be geographically co-incident with the locations of wave and tidal energy projects
2. **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
3. **Mode of transport in high current speeds** – the degree to which passive transportation through areas of high energy takes place, and potential implications
4. **Encounter Effects** – if some fish do make physical (or equivalent) contact with the wave or tidal energy device, what are the outcomes.

5.4 Research

5.4.1 Research Priorities

Marine Scotland published a paper setting out research priorities for marine renewable projects in 2011, and Table 11 shows some of the details relating to migratory salmonids.

Table 11. Research priorities identified by Marine Scotland[83].

No.	Possible Research Project	Description
MF 1	Measurements of audiograms for key fish species - salmon, sea trout, eels, herring, cod and Sandeels (Work Package A1 Migratory Fish)	
MF 2	Modelling the consequences for Salmon of exposure to piling and operational noise (Work Package A2 Migratory Fish)	Proposed project to model effects and potential impacts of construction methods and operational noise to Salmon in Scottish waters
MF 3	Modelling exercise of potential offshore wind farms to investigate audibility to migrating salmon and sea trout (Work Package A3 Migratory Fish)	Proposed project to model potential audibility of operating offshore wind farms to migrating Salmonids
MF 4	Investigation into Sandeel interactions with offshore renewable energy construction methods (Work Package A4 – Migratory Fish)	Proposed project looking at Sandeel behaviour during various construction methods of offshore wind farms
MF 5	Field investigation of effects of installation noise on fish hearing Work Package A5 – Migratory Fish)	Potential project to locate fish cages containing species, notably, salmon and sea trout, and monitor effects on behaviour
MF 6	Study of Sandeel habitat (Work Package Additional Project 1)	Proposed project to investigate % of habitat available, % of that available allocated to development;
MF 7	Review of COWRIE reports on skates and rays (Work Package Additional Project 3)	Proposed project to review and inform whether additional work required to inform licensing
MF 8	Study on population numbers of Basking Sharks (Work Package Additional Project 4)	Proposed study to identify population and distribution in Scottish waters; potential to expand to include sensitivity to EMF, disturbance and noise and identify mitigation;
MF 9	Collation of data on Salmonid populations in the	Project to collect all available data on species

[83] http://www.scotland.gov.uk/Topics/marine/marineenergy/ris

	Solway region to assess the potential influence of the Robin Rigg offshore wind farm development (Work Package Additional Project 5)	within the Solway Firth
MF 10	Analysis of fish and fisheries data to assess the potential impact of offshore wind development on Solway rivers (Work Package Additional Project 6)	Analysis of the fish and fisheries data to assess potential impact of offshore wind development on the Solway rivers, building on the data collected through WP AP 5
MF 11	Migratory Fish Research	Phase 1 – Construction of a coil system to investigate electro-magnetic force impacts on Salmonids
MF 12	Migratory Fish Research	Phase 2 – Evaluation of genetic methods for assigning fish caught in coastal zones to river of origin
MF 13	Migratory Fish Research	Phase 3 – Evaluation of options for establishing the migration routes of Atlantic Salmon in coastal areas
MF 14	Migratory Fish Research	Potential for marine renewable power developments to affect diadromous fishes in Scottish waters: informing EIAs

Marine Scotland has published an updated (early 2013) paper on PFOW migratory salmonids and eels research, which discusses some of the key issues, and how they might be addressed. The need to carefully scope out specific research projects is highlighted.

5.4.2 Current Research

Key current active research projects are summarised below:

- **MSS work on EMF using a test tank.**

  A purpose-built facility at the Aberdeen Marine Laboratory is currently undertaking a sequence of studies on the effect of a.c. EMF on migratory fish species. There are clear end-points for the work, and results should become available in the near future.

- **ERI work on migratory fish**[84]

[84] See: http://www.nhconline.net/eri/resources/newsletter_summer2012.pdf + Pers com Alan Youngson Feb 2013.

Funded by The Crown Estate, this particle modelling project involves a significant review and a compilation and assessment of historical data. Its main aim is to bring together particle behaviour assessments (based on considerable hydrodynamic information available for the Pentland Firth) and biological characteristics.

- **Tagging work being undertaken by MSS in 2013**

  With funding support from The Crown Estate, this project will involve satellite tagging of adult salmon caught on the north coast. It should provide information on swimming depth, as well as migratory routes.

5.4.3 Research being Scoped

Scoping work is underway on:

- **Acoustic tracking for post-smolts.**

  Installations of hydrophone sensor arrays can be used to track the movements of small fish such as salmon smolts, fitted with acoustic tags. Modern designs of these small tags can also provide information on depth of the fish.

  Undertaking this type of work in high energy (and high ambient noise) areas such as the Pentland Firth is perceived to be very challenging, and the current focus is on commencing in less demanding areas. Information arising from these early studies might indicate whether there is any need to extend the work into higher-energy areas in the future – but see also 5.3.

- **A network of fish counters.**

  This topic is discussed in part 5.5.

5.5 On-Site and Other Strategic Initiatives

5.5.1 Counting Fish

As discussed in Chapter 3, there is a long time series of salmon and sea trout catch statistics in Scotland, dating back to 1952. There is also data on fish numbers in rivers from a number of counting devices[85], some of which have been operating for many years. There is therefore a good understanding of 'before' wave and tidal projects fish numbers, down to a scale that takes into account the rivers opening into the PFOW area. This is the baseline information discussed in part 5.2.

Having a baseline data set leads to the concept that monitoring **fish numbers** carefully after deployment of wave and tidal energy devices might be helpful in indicating any effects of the

[85] http://www.snh.org.uk/pdfs/publications/commissioned_reports/F01NB02.pdf

installations (albeit other factors could also influence the baseline). The ASFB has suggested that fish counters, which might be considered to be more accurate than mandatory catch returns (the basis of the MSS statistical database), should be installed in some or all of Scotland's SAC rivers.

There is considerable natural variation, year to year, in the numbers recorded in individual rivers, whether by catch statistics or by fish counters, as Figures 19 and 20 illustrate. Data are presented from two different rivers by way of illustration. The River Thurso data includes rod and line capture, both retained and released.

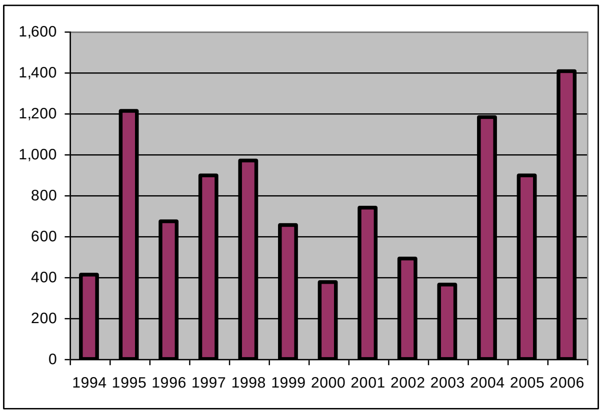

Figure 19. All salmon catches in the River Thurso. Source: MSS

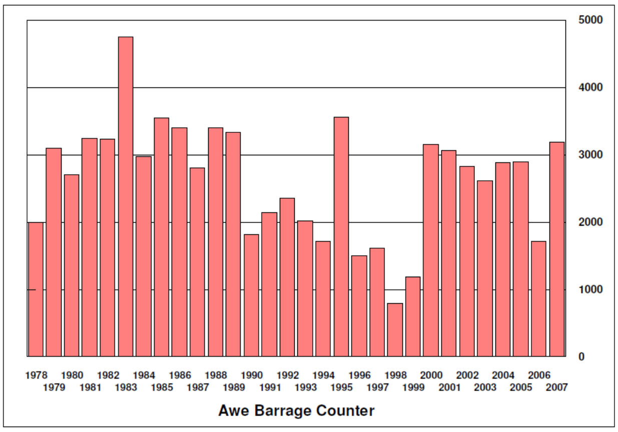

Figure 20. Awe Barrage counter data. Source: Author's files.

The key point to be taken from Figures 19 and 20 is that inter-annual variations are – or can be – quite large.

An SNH report on Scotland's fish counters[86] provides an analysis of counter information compared with data from the fisheries catch statistics. The correlation is very close, and the observed differences could be attributed to specific issues identified at the sites.

SSE maintains 18 fish counters around Scotland, as part of its statutory monitoring regime. It has offered to make all of its data available to MSS for analysis[87].

Considering all of the points above:

1. This study is not convinced that using fish counts, however undertaken, **will allow rapid and accurate identification of any local impacts from individual small scale wave or tidal energy projects over a short timescale** – unless they are so severe that they overcome the natural annual variation in counts / abundance
2. On the other hand, and taking a longer term view of advancing knowledge about migratory salmonids in Scotland, this study concurs that the public sector should be encouraged to invest in effective fish counting technology, especially in SAC rivers.
    a. Taking into account offshore developments of all types that might take place **outside** the PFOW area in the future, it is compelling to consider that the installation of fish counters in all SAC rivers might be justified
    b. In addition, a new network of counters may provide valuable information that relates to interactions with other sectors, not just those focused on marine renewable energy.

This study takes the view that a contribution to the cost of the installation and operation of counters is not generally appropriate or proportionate for PFOW developers.

5.5.2 On-Site monitoring – Cameras and Related Devices

Obtaining more information about migratory behaviour and swimming depth behaviour will help to determine whether migratory salmonids will become physically co-incident with specific wave and / or tidal energy projects, and hopefully also provide some indication as to potential numbers that might be involved. It may be the case that for some specific projects or types of equipment, there will be no justification for further 'on site' knowledge acquisition.

However, where there is likely to be a degree of physical co-incidence, it would be helpful to expand our knowledge about what the effects might be. One obvious way of doing this is to monitor operational devices / first arrays.

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86 http://www.snh.org.uk/pdfs/publications/commissioned_reports/F01NB02.pdf
87 Alastair Stephen, personal communication, January 2013

Observing what happens to fish *in situ* is likely to prove challenging. Ideas such as deploying nets 'behind' turbines in order to capture fish and assess their state are probably not feasible: current speeds are too severe for such difficult activities.

One approach that has been considered and tested in various parts of the world is the installation of sensors on the marine energy devices (mainly tidal turbines) in order to ascertain its interactions with different species. Underwater cameras, with high intensity strobe lighting to overcome visibility challenges, can be hybridised with sonar and similar equipment[88] - Figure 21. Results of trials so far appear to be quite encouraging, although the equipment is quite expensive. Attempts to use a combination of hydro-acoustics and other techniques such as netting for validation have been promoted for the Verdant Power project near the Roosevelt Islands. The use of so-called Didson[89] (fixed dual identification sonar) "cameras" is included[90].

Marine Scotland is interested in the possible use of Didson equipment, and Figure 22 shows both the type of equipment and the possible images it can capture.

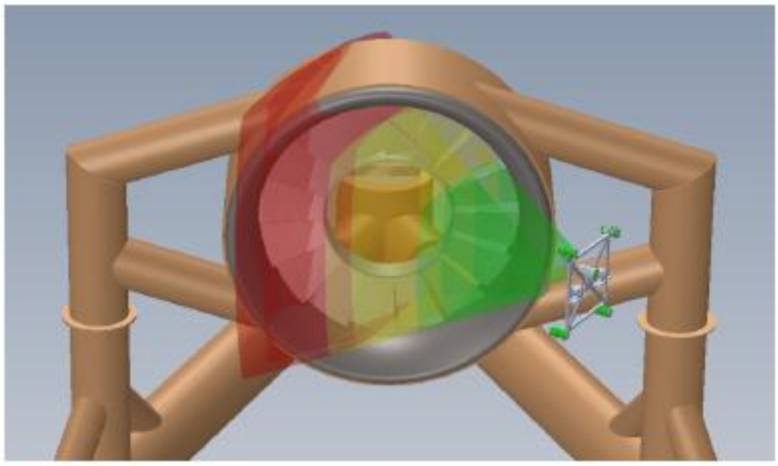


Figure 21. A hybrid sonar/optical camera mounted on an Open Hydro turbine.

[88] http://depts.washington.edu/nnmrec/docs/Joslin%20et%20al.%20%282012%29%20-%20Development%20of%20a%20stereo%20camera%20system%20for%20monitoring%20hydrokinetic%20turbines.pdf; http://depts.washington.edu/nnmrec/project_meas.html;

[89] http://www.didson.com/

[90] http://www.see.ed.ac.uk/~shs/EWTEC%202011%20full/papers/57.pdf

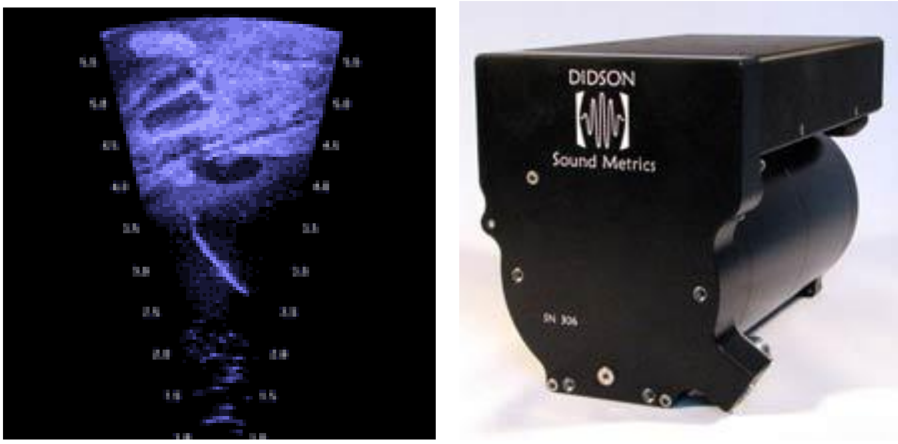


Figure 22. A Didson 300 m device and an image of barracuda.

Discussions with PFOW developers have suggested that their understanding is that the use of direct sensors on equipment is still problematic. Visibility is very challenging in the PFOW area, and unless a system can accurately and reliably show what, if anything, is encountering the turbine or its immediate vicinity, deployment would not be justifiable. It is clear that further development work and testing of different types of direct observation equipment is required, if developers are going to have the confidence to deploy such equipment.

The other key points about such direct observation techniques are that:

- They would only need to be deployed on a sub-sample basis
- They would only need to be deployed for an initial 'investigatory' period. As soon as sufficient information about fish passage through the machines has been obtained, there would be little value in maintaining the equipment for a longer time frame. This offers the possibility that direct observation equipment could be moved (if necessary) to different tidal energy projects as they too are being deployed. If this proved practical, it would reduce overall cost, and / or allow for relatively expensive and sophisticated equipment to be contemplated.

Direct observation methods may not enable understanding about other possible interactions, such as avoidance behaviour and possible disorientation slightly further away from the array. However, it is difficult to imagine how such behaviour could be observed in the field.

5.5.3 On-Site – Tag Sensors

As discussed in Chapter 4, deployment of tag sensors (hydrophones) as stand-alone research tools is considered overly challenging in high energy environments such as the Pentland Firth. The tidal currents are likely to severely displace the sensors, which have to be moored / buoyed to hang stationary in mid water.

It is possible, however, that once tidal energy turbines have been deployed, their rigid physical structure might provide a platform for mounting hydrophones – thus allowing experimental observations on tagged smolts.

Further work is required to scope out whether such an approach is feasible and likely to deliver high quality information. It is interesting to speculate that, if it were feasible, it could be either an addition to cameras and related devices, <u>or an alternative to them</u>. The rationale for the latter scenario would be that if tagged smolts were never (or very rarely) detected in close proximity to tidal turbines, there would be little value in deploying ‘visual’ (or equivalent) sensors.

5.5.4 Boat-Mounted Tag Sensors

Another option for tracking the movements of salmon with tags has been suggested by the workshop Chairman, Professor Tony Hawkins. Sensors could be mounted to boats, and released tagged fish could be effectively ‘followed’ in real time as they migrate along the coast.

5.5.5 Genetic Assessment

One of the consultees to this study has identified an additional possible research approach, and we are led to believe that MSS is also looking into this. Recent advances in genetic techniques, applied to Scotland’s wild salmonids, offer the prospect that in the near future it may be possible to identify the main river (or at least region) of origin from a salmon caught anywhere, by assessing its genetic makeup. If this were the case, then fish caught by the netting stations (i.e. while they are still in the marine environment and possibly *en route* to their natal river) in the Pentland Firth could be sampled and assessed as to likely final destination.

6 SUMMARY

The main findings of this study, which helped to provide discussion points for the workshop, are:

1. The need for marine renewable energy development, including wave and tidal, as part of Scotland's current and future energy 'mix' is evident, and the support of Scottish Ministers for the marine renewable energy developments in the PFOW area (and elsewhere) is clear
2. The social and economic values of the wave and tidal projects are high at a national level, but also significantly important at a local level
3. Migratory salmonids have importance because of their conservation status, but also because they fuel local and national commercial angling and netting businesses, which also have economic and social value
4. There are some outstanding knowledge gaps in relation to migratory salmonid locations and behaviour and therefore to the impacts wave and tidal energy developments might have on stocks of migratory salmonids, whether at a local level or at a national level
5. There is a good understanding of the scientific research that is required in order to fill knowledge gaps. Some of it is underway, but other topics are still being 'scoped' in terms of detail and cost
6. Despite the lack of complete knowledge in all areas of possible interactions, there does appear to be some evidence for a general overview, relatively widely shared between contributors to this study to date, that:
    a. Tidal energy projects probably represent higher levels of risk than wave energy projects
    b. The seven wave and tidal projects out-with the Pentland Firth ***may*** present a lower level of risk to migratory salmonids
    c. The main concern appears to be the consequences of direct encounters between fish and the tidal devices. Noise and EMF still require further research, but are currently seen as less significant
    d. Even direct physical co-incidence between turbine blades and fish may not necessarily result in significant damage to the fish – although further investigation is required

7. In that context**, there is a view that if small-scale deployments (but of commercial scale devices) could be established as a 'first step', and their effects observed, the process of licensing wave and tidal energy projects could be de-risked very substantially in the future**
    a. The decision by one of the most advanced-stage developers (in application terms) to deploy just six tidal energy devices (should consent be forthcoming) initially presents an excellent first opportunity to observe interactions and effects, with lower overall risk
    b. As a continuum of this approach, deployment of other wave and tidal energy equipment will be phased (see Section 2) over quite extended periods of time – allowing for yet more opportunities to advance knowledge and scientific certainty.
8. Observing the effects arising from the deployment of a small number of devices, particularly at this early stage, is important, and it deserves a high priority in terms of resource-allocation and innovative thinking about research design
9. It is necessary to be clear that whilst the small-scale start-up to deployment (and observation) is an advantage, knowledge outcomes should be robust and timely
10. In parallel, it is important to add to our understanding about salmonid migration and swimming behaviour, so as to address the question of physical co-incidence on a site by site basis
11. Direct observation on-site, whilst still challenged by technical and practical concerns, offers one route for gaining valuable information over a short time frame – whilst in no way replacing or displacing the ongoing wider-field migratory and swimming behaviour (i.e. 'primary') research
    a. Direct observation could involve cameras, Didson devices and other similar equipment
    b. Direct observation (albeit on a structured research project basis) could involve acoustic tag sensor arrays
12. Modelling, and specifically encounter modelling, is now an accepted tool for ongoing regulatory decision-making in other related sectors. A good start has been made for tidal energy developments in the PFOW area, and this should be built-upon in a rigorous and peer-reviewed manner

13. Consideration of public sector investment in additional fish counters in Scotland is warranted over the longer term.

7 WORKSHOP DISCUSSION POINTS

The DP (Chapters 1 to 6) was presented to delegates attending The Crown Estate workshop in April 2013 in Thurso, Caithness, on Marine Renewable Energy Projects and Migratory Salmonids in the Pentland Firth and Orkney Waters[91] (PFOW) area. Its purpose was to provide a synthesis of what is currently known about potential interactions between wave and tidal energy projects and migratory salmonids, and to provide a structure for discussions during the workshop. This structure took the form of a number of topic-related 'questions' for workshop groups to discuss, as outlined in Sections 7.1 to 7.9.

7.1 Interactions

Potential modes of interaction between wave and tidal energy devices and migratory salmonids (assuming they are sufficiently co-incident for there to be an interaction) include noise; EMF; and encounters. The DP has presented information on what is known about some of these, and a workshop presentation also summarised these. Subject to further results from ongoing research and consultation, the main interaction of concern to UK regulators, advisors and stakeholders is that of **physical encounter** between tidal devices and migratory salmonids (SNH, 2013, pers. comm. January). There is much less concern, or the risks are considered much lower, in relation to wave energy converters, EMF and Noise.

Question 1.

On the basis of the evidence presented and your own knowledge and experience, which of the potential interaction-types are of most relevance or importance for:

a) Wave energy?

b) Tidal energy?

Please note that this question has overlaps with those relating to knowledge gaps and knowledge acquisition.

7.2 Baseline knowledge

Existing (or 'baseline') knowledge that is important with respect to wave and tidal energy projects and migratory salmonids in the PFOW area includes topics such as migratory pathways, swimming (active and passive transport; depth) behaviour, and ultimately the possible effects of interactions.

[91] Hereafter referred to as PFOW

Developers are being asked (Environmental Impact Assessment (EIA) Scoping) to provide considerable information about some of these issues for their particular locations, and might have hoped for more information to already be resident within the District Salmon Fisheries Boards (DSFBs), Marine Scotland Science (MSS) and other groups. New primary research to answer some of the questions may be unreasonably and disproportionately expensive, and / or technically very challenging.

Question 2 (in two parts).

a) Are any workshop delegates aware of additional knowledge in any of the topics that are not apparently being utilised at this time – e.g. knowledge about salmonid movements / presence in specific areas?

b) Given our current state of baseline knowledge, could the workshop make recommendations as to what should be expected from developers in their Environmental Statements and submission of data for Habitats Regulations Appraisal (HRA) / Appropriate Assessment (AA)?

Please note that this question has overlaps with several other questions,

7.3 Different Types and Locations for Wave and Tidal Energy Projects

The types of energy device and the sites where they will be located are described in the DP were covered by presentations to the workshop. There are different designs for each type (wave and tidal energy), but overall there may be a belief that wave energy devices pose potentially less risk to fish than tidal energy devices. There is also the suggestion that projects in the waters around Orkney are less likely to be physically co-incident with large (numerical) concentrations of migratory salmonids than those in the narrows of the Pentland Firth, and therefore pose less overall risk.

Question 3 (in two parts).

a) Is it reasonable to differentiate between different projects using different types of wave and tidal energy devices and proposed for location in different areas (i.e. case by case), in relation to requests for information during EIA / HRA / AA, and in relation to assessment during consenting decision-making?

b) If the workshop agrees this to be the case, could it make specific recommendations?

Please note this question feeds back also into the discussions around Question 2 – the response to 2b might take into account ideas / guidance from this question. Please also note the DP's general understanding of the situation: there may be reduced level of potential risk for some types of developments, and those in some locations.

7.4 Knowledge Gaps

The workshop heard about knowledge gaps, and some of these are discussed in the DP. In large part they appear to relate to topics that are already under consideration as 'baseline' topics: we have some knowledge in all these areas, but would prefer to have more.

Question 4.

Can workshop delegates advise on whether any categories of 'knowledge gap' have not yet been fully identified and discussed, and do they have any recommendations about prioritisation of knowledge gaps as whole?

Please note this question overlaps with Question 1 (baseline knowledge) and Question 5 (acquisition of new knowledge)

7.5 Strategic new research / knowledge acquisition

The current research that is underway to address knowledge gaps and improve our general understanding of key issues were presented during the workshop, a number of which are summarised in this DP. In addition, there are several pieces of research currently being 'scoped' in terms of their detail and resource-requirement. Other knowledge acquisition topics have also be presented for the workshop's consideration. To briefly summarise, the DP suggests that the key areas for knowledge acquisition are:

- Improving understanding of where migratory salmonids might be physically co-incident with individual projects, and if they are, at what scale and over what periods of time (e.g. seasons of the year)

- Improving understanding of swimming behaviour, such as depth preference, avoidance capability and behaviour in strong currents
- Improving understanding of the effects of interactions, if they do occur.

The first two areas of knowledge are critical: **If the fish are not there, the types of interaction discussed in this DP would not occur.**

Detailed on-site observations of effects post deployment are covered below, in Question 6.

Question 5.

Discuss and agree on knowledge acquisition priorities, taking into account what is currently taking place, what is in the planning stages, and what new initiatives might come forward.

Please note this question relates to several others.

7.6 Initial Small Scale Deployment

The majority of developers have proposed to phase device deployment, which appears to offer an opportunity to allow this important sector to develop, whist at the same time reducing potential risk to migratory salmonids (and other receptors) and allowing for increased knowledge acquisition.

Question 6.

What are your recommendations on the steps that need to be taken to ensure the 'start small scale' opportunity is effective in the long term?

Please note this is an open question that could attract different kinds of answers. The issue of on-site observation of the effects of deployment (if any) is relevant within this question, and recommendations in the DP and from the workshop are important.

7.7 Modelling

Encounter modelling (such as that based on the Band Model used for modelling ornithological collision risk with wind farms) is discussed in the DP and presented as a useful tool to continue to develop and utilise. The applicability and value of such models will improve as baseline knowledge is enhanced, since the modelling assumptions will be more evidence-based. This type of modelling is based on the assumption that encounters (particularly blade strike or close proximity) are possibly the most important types of interaction between tidal energy projects and migratory salmonids – and this assumption is yet to be tested or verified.

Question 7.

The DP supports / encourages the further development of encounter modelling for salmonids. What are your views on putting additional resources into developing improved encounter models?

7.8 Cumulative and In-Combination Effects

Cumulative and in-combination impact assessment is fundamental to both the EIA and the HRA / AA process, and guidance is being produced on 'Cumulative Impact Assessment' (CIA). Case studies inform us that this is one of the steps which can be less than satisfactorily covered in some EIAs.

Question 8.

As knowledge of the presence or absence of migratory salmonids at specific locations improves, and as modelling techniques become increasingly evidence-based in terms of assumptions, the ability to conduct CIAs for projects will improve. Bearing in mind the current state of baseline knowledge, and the steps being taken to acquire new knowledge and bridge knowledge gaps, what recommendations could you make about how the CIA process should be applied in respect of the PFOW projects and migratory salmonids at this point in time?

Please note this question is quite open, but is prompting a discussion that should result in ideas for well-defined approaches that are reasonable and proportionate for the present, and possibly evolving for the future.

7.9 Additional Topics for Discussion

Workshop discussions were generally based around the eight questions above, but delegates were invited to introduce other topics, as long as they were:

- Relevant to the subject; and
- Capable of being resolved in the sense of finding an agreed approach to it, after peer debate.

Question 9.

Are there any other issues or topics, not already covered, that you would like the workshop plenary or sub-groups to discuss?

Please note that it would be helpful if delegates wishing to raise topics not covered in this DP could contact Epsilon Resource Management in advance of the workshop, so that sufficient time and resource can be devoted to these topics.

SECTION B. SUMMARY OF WORKSHOP OUTPUTS

8 WORKSHOP OUTPUTS

8.1 Introduction

This chapter summarises the main outputs from the workshop.

Detailed proceedings of the workshop can be found in Appendix 1. In addition to presentations from a range of experts, the workshop held several 'table group' and plenary discussions.

8.2 Interactions

The workshop discussed the types of interactions that could occur between wave and tidal energy devices and migratory salmonids, and agreed that physical encounter, or **collision**, **noise** and **EMF** were the most important ones to consider.

Whilst the DP had indicated an assumption (on the part of some consultees) that collision effects were likely to be the most important in terms of possible negative impact on migratory salmonids, this emphasis was not fully endorsed by workshop delegates. Possible effects of noise and EMF were also debated at some length, and the final conclusion was that all three types of interaction should continue to be researched, in order to ascertain to what degree if any they presented a possible 'mechanism for impact' with migratory salmonids, and what the consequences of those interactions might be.

Although several participants stated their concern about the potential effects of noise and EMF, the review carried out as part of this project (see the Review and Discussion Paper) does indicate that potential collision risk with tidal stream turbines is the main uncertainty.

The potential effects of pile driving noise were raised by some participants. However, it was explained that drilling (which is inherently less noisy) will likely be the predominant construction method and piling is unlikely to occur in PFOW (see below for further detail on this). The suggestion was therefore that the (noise) effects of construction may be less than some may fear.

Possible cumulative effects were also discussed, but it was noted that there was insufficient knowledge to fully consider these at this time.

8.3 Presence or Absence of Migratory Salmonids

If migratory salmonids do not in fact swim (or are not tidally transported) close enough to the actual areas where the energy devices will be installed for there to be a measurable impact from collision, noise or EMF, then there can be no significant or adverse effect on the integrity of SACs designated for Atlantic salmon and freshwater pearl mussels as a result of consenting wave and tidal energy projects. It would therefore appear that answering this question is a research priority for all involved in developing, sponsoring and regulating this new industry.

It was noted that there are genetic 'stock components' within migratory salmonid populations, and that consideration of these is also important. There is therefore a seasonally-related aspect to understanding the behavior and presence or absence of migratory salmonids in the PFOW area.

It was noted that it may not matter where the fish are if there is no evidence of an impact mechanism. So there are two key priorities:

a. Understanding impact mechanisms

b. Finding out where the fish actually are.

Therefore, while research into the locations of migratory salmonids is underway (see Chapter 5), it is also necessary to continue to work on aspects of what would happen if it transpired that some fish were likely to be physically co-incident with proposed energy devices (also see Chapter 5).

Research themes that bridge the two areas include the **particle tracking** (with behavioural overlay) and **encounter / collision modelling**, which were both discussed and generally supported by delegates at the workshop.

8.4 Tagging

Tagging is potentially difficult and costly to undertake. However, attendees at the workshop were clear that it should not simply be assumed that establishing suitable arrays of hydrophone sensors and undertaking tagging experiments (including with smolts) is 'too difficult in these harsh environments'. The overview was:

1. The satellite tagging work that Marine Scotland are currently undertaking was welcomed and participants were keen to see the outputs made available as soon as possible
2. With collaboration between organisations with different sets of expertise, technical constraints for other tagging work could be overcome
3. By collaborating on funding, ways could be found to achieve what is required.

The authors find it interesting to note that whilst the Pentland Firth (and specifically the Inner Sound) may be very energetic, this is also true for areas of sea around Vancouver Island. Tidal and wave energy sites are being actively considered there – but there is also a range of hydrophone sensor arrays, installed as part of the Pacific Ocean Shelf Tracking Project (POST), nearby[92] – see Figure 23.

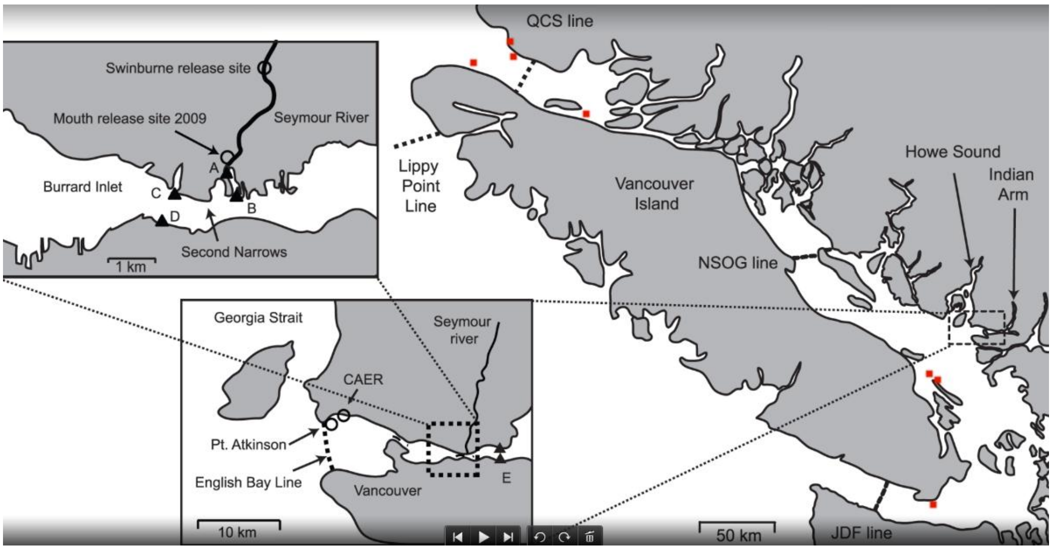


Figure 23. Proposed tidal energy locations (red dots) and POST sensor arrays (black dotted lines) around Vancouver Island – main part of the image.

It may be that, after a collaborative effort to scope this sort of deployment of acoustic sensors, consensus is reached that it *is* too difficult or expensive. Because of this, more limited potential for more targeted deployment of sensors on early-deployed tidal energy devices, as presented to the workshop by MSS, should also be separately scoped.

8.5 Collaboration in Research

There was much discussion during the workshop about collaboration in designing, funding and implementing research. Several delegates stressed the need for research contractors and providers to 'think outside the box', and work with others who could contribute ideas and expertise.

There were several pleas from delegates for a better degree of organisation in how research funding could be sourced and utilised effectively. Some delegates voiced their hope that outputs of this project would assist with this. Reference was also made to a wave and tidal energy equivalent of the Offshore Renewables Joint Industry Programmes (ORJIP) initiative. It appears that progress has been made on this topic, subsequent to the workshop and this should be welcomed.

[92] See: http://www.postprogram.org/page.php?section=about; http://srmprojects.ca/wp-content/uploads/2012/12/SRM-North-VI-Tidal-Energy-Presentation-26Nov2012.pdf; http://www.postprogram.org/page.php?section=about; and http://www.timescolonist.com/news/local/tidal-energy-generating-turbines-pitched-for-island-waters-1.57425

8.6 Small Scale Deployment and Effective Monitoring

Generally it was agreed that Marine Scotland's approach of small scale deployment and effective monitoring (and not necessarily solely down to the developer to carry out) is the best way forward. However, for stakeholders to be comfortable with this approach, it appears that the following would be helpful:

1. An understanding as to what degree of 'baseline' information is required for the consenting of initial deployments

2. A definition of 'small scale'

3. A distinction between monitoring requirements for different sizes and types of development

4. General details of the sorts of monitoring that might be undertaken; length of monitoring; who is going to pay for and 'manage' it etc.: i.e. a high-level **monitoring approach**

5. A methodology for interpreting the results of monitoring and being able, from that, to ascertain any **actual** effect of the deployment (or a subsequent larger-scale deployment) on a designated site. This should be built into the design of the monitoring programme (see 3. above)

6. Clarification from Marine Scotland for what will happen if monitoring or any other knowledge-acquisition activity results in a concern that a significant negative effect is likely.

8.7 Expectations in EIA / HRA / AA

Three components to this issue were raised at the workshop, one briefly (but clearly), and the other two in rather more detail:

1. Developers need to have a very clear understanding of the potential impacts from their proposed project, and ensure that there are noted fully in any documentation submitted during the application process. Possible impacts include:

    a. Details of the likely EMF 'fields' around all parts of their proposed development, including cables, generating equipment, etc. – and taking into account mitigating approaches such as Horizontal Directional Drilling (HDD)

    b. Details of the likely noise energy (intensity, frequency, etc.) around their proposed development, at varying distances and set against a backdrop of a sampled understanding of the baseline (before-deployment) noise features of their proposed location

i. During construction / installation – including duration, season, etc.

ii. During operations

c. Physical and movement (e.g. turbine blade speeds) aspects are probably already well understood, but obviously still need to be clearly set out.

These would not be unreasonable requests on the part of a regulator, and would be asked of any other developer, in any other sector, in 'EIA Projects'. Developers clearly accept and appreciate this requirement.

2. The discussion at the workshop was also relatively clear, on the other hand, that whilst collating and collecting as much baseline information as is **reasonably** available about the presence and behaviour of receptors is also an obligation of developers, there is a limit to what can reasonably be asked of them. If nobody else knows the exact location of migratory salmonids in relation to a specific grid reference in the PFOW area (taking into account additional information sources, which are not likely to be 'game changing'), it is unreasonable for individual developers to be expected to provide this information. Everybody agrees that as much baseline information as possible is desirable, but the workshop also agreed that there should be a wider funding-base for any research or studies that seek to improve our baseline knowledge about migratory salmonids – especially their whereabouts. The need for this knowledge is not just related to wave and tidal stream developments: offshore wind energy; offshore aquaculture, recreational and commercial salmon fishing and possible future offshore algal production are all sectors where this information would be valuable.

The issue of whether tidal energy developers should undertake **'encounter' or 'collision' modelling** was considered at the workshop. There was general agreement that the concept of these models was a good thing, but also agreement that much of the data needed to populate the models are lacking at this point in time. There was some negativity expressed by some delegates to the modelling attempt that has been made so far, not because the methodology was poor but because the information-input was difficult to substantiate. Nevertheless, the workshop agreed that modelling (including also particle tracking work) is important, and could be developed further – mainly by improving the quality of the input information. Modelling will be necessary in order to undertake quantitative assessment.

3. There was agreement that every development was different, and that a 'one size fits all' scoping advice was not appropriate. There are entirely different types of wave energy devices, and a range of possible tidal stream energy device types. Every location is different. MSS confirmed to the workshop that its current approach is based upon the recognition of case-by-case differences.

   Whilst on the face of it this workshop output appears to be pragmatic, it does pose some challenges – and particularly "what *should* the regulator ask for" on a case-by-case basis? The focus on demonstrating an understanding of **'pathways for possible impacts'**, was a helpful contribution to the workshop in this regard. The need to demonstrate a clear understanding of impacts has already been discussed above.

8.8 Acknowledge information that is available

The importance but difficulty of getting clear messages across was an interesting and informative outcome from the workshop. One example of this is the several references (and concern) regarding the issue of noise generated by 'pile driving'. However, it has previously been confirmed (via e.g. documents provided by developers and in the DP), and it was re-confirmed during the workshop, that 'pile driving' is extremely unlikely to occur in the PFOW area. Whilst the assertion that 'pile drilling' (as opposed the 'driving') involves much less noise, and will not affect migratory salmonids, has yet to be substantiated, the information provided that noisy pile driving is unlikely to occur in the PFOW needs to be recognised. If such information, when provided, it not heeded, it may be that unnecessary concerns remain and the areas which really require attention are overlooked.

This is only an example, relating to one particular aspect of development, but the implications are clear, and could be transferred to other aspects, such as effects of EMF and the available and growing body of evidence which needs to be used and recognised.

SECTION C. RECOMMENDATIONS

9 RECOMMENDATIONS

Participation at the workshop was comprehensive and detailed, and this report aims to reflect all of the contributions made by delegates. These cover a wide range of relevant topics, and in order to reflect the contributions fairly and accurately, the report is of some length.

The authors' final recommendations are presented below, based on the key issues. It is possible that **not all will agree** with the recommendations, but they have arisen from workshop outcomes which are clearly presented within the body of the report.

Table 12. Recommendations.

No.	Recommendation	Action
1.	The current Marine Scotland Licensing and Operations Team (MSLOT) approach to consenting wave and tidal stream energy should be continued and developed further. It is noted that this is an 'approach', and not a stated policy of Marine Scotland.	**Lead:** MSLOT **Also:** Developers, All Consultees
2.	Develop a high-level monitoring approach, including: • Which technologies could be used • Which technologies could be applied flexibly to different types of development (i.e. wave or tidal, but also for different types of equipment in either wave or tidal) • Who might undertake monitoring • Who might fund monitoring • Who should analyse monitoring outputs • Who should act, and in what way, in response to outputs from monitoring, having regard to protection of SAC rivers. Producing this high-level monitoring approach will provide developers with greater clarity as to the likely approach to and funding of any monitoring required at their projects, and will provide stakeholders with a better understanding as to how existing uncertainties will be investigated further.	**Lead:** Marine Scotland **Also:** Developers, All Consultees **Timescale**: ASAP
3.	Explore the establishment of a wave and tidal equivalent of ORJIP, to co-ordinate research prioritisation and research funding. Progressing this will enable a coordinated approach,	**Lead:** The Crown Estate, Marine Scotland and others

	focused on the key research priorities (including but not exclusively migratory salmonids) for the wave and tidal stream sectors, to be progressed.	**Timescale**: ASAP
4.	Continue to invest in research that establishes the behaviour and location of migratory salmonids at scales (numerical, physical and temporal). This will be useful in advising the consenting process of wave and tidal stream projects, having regard to the different types of developments that are foreseen. However, the information has much wider relevance too and this should be reflected in the involvement of other sectors in the necessary research.	**Lead:** MSS Also: SNH, salmon fishing bodies, researchers
5.	Continue to invest in research that establishes mechanisms for, and results of, interactions between wave and tidal stream energy devices and migratory salmonids if they were to be physically co-incident. Focus on collision risk as the key priority and ascertain whether/what further work is necessary regarding noise and/or EMF.	**Lead:** MSS Also: SNH, researchers
6.	Continue to develop and utilise modelling techniques (particle tracking, encounter, collision) for tidal energy stream projects, having regard to steadily improving information inputs resulting from research (see 4 and 5 above).	**Lead:** Developers **Also:** MSS, SNH, other researchers
7.	Clarify scoping advice to developers, having regard to: • An individual case by case approach (although cumulative effects should be considered where relevant, and guidance on this should be developed and promoted) • Different levels of risk due to type of equipment or location (or both) • Consent applications (and accompanying Environmental Statements) including a detailed assessment of the likely significant direct and indirect impacts arising from the proposed development • Developers presenting a comprehensive understanding of the baseline situation (in this case for migratory salmonids) in so far as they can reasonably obtain the information	**Lead:** MSLOT **Timescales**: from now on

	from **existing** sources • Developers **not** expected to undertake additional primary research to gather migratory salmonids baseline information (i.e. into fish behaviour, etc.) • Developers to make their best efforts to demonstrate their understanding of 'pathways for possible impacts' approach in their applications / submissions	
8.	Improve communications in general, and specifically: • Publicise all new research outputs widely and appropriately (in terms of media and language) • Consider establishing a Liaison Group to facilitate information exchange, with representation from science, policy, developers and key migratory salmonid stakeholders in PFOW • Clarify (on a case by case basis) the distinction between actual development footprints and the initially large Agreement for Lease (AfL) areas agreed by The Crown Estate • Encourage developers and all parties to collaborate in pre-application discussion, as a matter of best practice. It is expected that this will assist with clarifying existing uncertainties and therefore the research priorities, and ensure that aspects which are increasingly well researched and/or understood are acknowledged and the relevant information fully utilised.	**Lead:** All parties **Timescales**: from now on

Appendix 1 Workshop proceedings

A1 Introduction

The workshop was held at Caithness Horizons in Thurso on the afternoon and evening of the 17th and morning of the 18th of April, 2013. There were over 40 delegates invited to the workshop (Appendix 2), representing a range of interests including: developers, commercial recreational fisheries, fishery boards and public sector science and policy organisations.

The workshop structure is illustrated in Table 1.

Table A1. Summary of Workshop Structure.

Day 1
Introductions: The Crown Estate and the Chairman

Presentations:
• Marine Renewable Energy:
    o Tidal
    o Wave
• Migratory Salmonids
• Licensing and Interactions:
    o Licensing
    o Interactions
• Research:
    o Marine Scotland Science Overview
    o Environmental Research Institute Project

Plenary Discussion Session 1
Evening - short pop-up presentations: Marine Spatial Planning; Collision Modelling for Wind Farms; Collision Modelling for Tidal Energy; Noise and Fish; Tracking Tagged Fish.
Day 2
Introductions
Group Working Session 1
Group Working Session 2
Plenary Discussion Session 2
Summaries: The Crown Estate and the Chairman

The group working sessions were based upon considering the first eight ‘questions’ posed in the Executive Summary of the Discussion Paper, and delegates were encouraged to raise additional points when addressing question nine. Participation was excellent, with most delegates having a part to play as a speaker, a group facilitator or rapporteur.

This appendix presents a record of the proceedings of the workshop, and is therefore structured according to the elements in Table 1. Discussion and interpretation of the workshop outcomes were presented in Chapter 8.

The evening pop-up presentations were both interesting and informative, but were conducted informally and in a semi-social setting, and therefore are not fully reported in this document but the presentation slides used are available in Appendix 4.

A2 Presentations and plenary discussion session 1

2.1 Summary of Presentations

Full copies of the presentations made to the workshop can be found in Appendix 3. It is not possible to summarise them in a consistent way in this section of the report, since not all of the presentations contained a summary slide (or slides). The details presented to the workshop are important, and it is not appropriate for the authors to attempt to interpret these independently.

A list of the subject matter and the presenters is shown below:

Marine Renewable Energy – Tidal

Presenter: Ed Rollings, Meygen Ltd

Presentation: see Appendix 2 a

Marine Renewable Energy - Wave

Presenter: Laura Carse, Pelamis Wave Power Ltd

Presentation: see Appendix 2 b

Migratory Salmonids

Presenter: Alan Wells, Association of Salmon Fishery Boards

Presentation: see Appendix 2 c

Licensing

Presenter: Roger May, MSLOT

Presentation: see Appendix 2 d

Interactions

Presenter: Ian Davies, MSS

Presentation: see Appendix 2 e

Marine Scotland Offshore Renewable Salmon Research

Presenter: John Armstrong, MSS

Presentation: see Appendix 2 f

Particle Tracking Models for Salmon

Presenter: Angus Jackson, ERI

Presentation: see Appendix 2 g

2.2 Discussion Session

The following section contains a (non-verbatim) record of both the questions / answers that followed individual presentations, and then the more general question / answer session that followed thereafter. The authors have recorded the issues as accurately as possible, but are not able to add further contextual detail or to comment on the accuracy of statements.

2.2.1 **Question:** Concern that a tidal energy development could result in a "huge amount" of EMF.

Response: Cables are low voltage, therefore potential for EMF is reduced.

2.2.2 **Question:** Will the cables be buried or laid on the surface?

Response: It is not necessarily possible to bury the cables at all locations. In such locations, they are therefore likely be laid on the surface and armoured, although it might be possible to lay cables sub-surface (e.g. directionally drilled) in the near-shore area (and therefore only be surface laid in deeper water).

2.2.3 **Question:** EMF – what is the comparison between free floating and buried cables.

Response: Cables are low voltage, therefore potential for EMF is reduced. But floating cables are likely to produce higher EMF, as there is no shielding from rock armouring / burying etc.

2.2.4 **Question**: Clarify 'survey, deploy and monitor' (SDM) approach and potential for in-combination effects

Responses: SDM purpose / focus is on low risk deployments – it does not reduce the need to meet Natura 2000 obligations, HRA etc. Work is ongoing on in-combination and cumulative impact issues

2.2.5 **Question:** Do acoustic tags have GPS? (MSS points out that the tags to be used are not acoustic)

Response: No, but can programme when the tag releases. Route is expected to be easterly

2.2.6 **Question:** Are there possible positive effects of such developments e.g. fish attraction?

Responses:

1. 'Fish aggregation' could be both positive and negative e.g. aggregation of prey species
2. Difference between migratory species and resident species, and that the positives were likely to be small
3. Positives for commercial species, and possibly sand eels (although these are unlikely in tidal stream areas). Likely positives currently considered more so for offshore wind than wave and tidal

2.2.7 **Question and Observation:** There is experience of onshore wind development, and the 'net benefit' that such developments could bring about. Any policy developed should be framed around the question of "what good could be done". In essence, a question about 'planning gain' expectations, especially within the DSFBs / Trusts, and also possibly about compensation issues.

Responses:

1. Income from salmon fishing was modest, and therefore what could be given back was also modest. There needs to be a "business case".
2. Mitigation and enhancement measures are considered through the EIA process.
3. The existence of the Coastal Communities Fund and European Fisheries Fund were highlighted.

2.2.8 **Question:** What conditions could be attached to consents.

Responses:

1. Difficult to quantify. Focus of conditions would tend to be on: monitoring, construction and operation, and mitigation.
2. It was noted that specific requirements had been used in onshore developments
3. It was agreed that that was a policy decision for Marine Scotland, and that it would be referred back to MS by one of the workshop delegates

2.2.9 **Question:** More information about noise, particularly sub-lethal effects – salmon 'listening for predators' and behavioural changes.

Responses:

1. Whilst it is possible to establish hearing thresholds, behavioural effects are 'more difficult' to establish. Sound models could be developed of possible sound fields, from which it would then be possible to predict effects.
2. Possible effects included:
    a. Death / injury – vary between species. Pile driving specifically mentioned.
    b. Temporary Threshold Shifts – high source levels required. Also differentiated between impulse and constant noise sources.
    c. Masking – sound of breaking waves used to navigate – suggested, but not demonstrated. Therefore, potential impact on navigation of migratory fish.

d. Behavioural reactions (in wild) – responses variable, and would need to know 'normal' behaviour. Only possible to observe in wild

3. The distinction between pile driving and pile drilling was raised. In the case of the latter, it was noted that vessel noise typically had a greater sound intensity. This topic repeatedly came up during the workshop, and it was clear that one key message needed to be emphasised:

Text Box 3

The noise from pile driving was raised as a key concern by a number of delegates at the workshop. Clear statements at the workshop outlined that due to the rocky seabed locations of most wave and tidal developments in the PFOW area, it **is impossible to carry out pile driving, as carried out by offshore wind farms into sediment, since there is no sediment overburden into which a pile could be driven**. This is possibly not definitive for all PFOW developments; some offshore wave developments may be over areas of sediment but the understanding is that these would be anchored rather than piled.

W&T developers have often had to dispel the common expectation amongst stakeholders that their installation activities are noisy due to pile driving taking place. In reality they are most likely to carry out pile **drilling** which has a lower sound intensity than pilling and also compared to vessel noise – it is essentially a very large, heavy drill bit rotating slowly on the seabed and grinding away the rock, rather than noisy impact piling.

It is important to reduce what appears to be potentially unnecessary concern on this issue and to change the perception that pile driving will be the standard method of installation.

4. It was anecdotally noted that in Scrabster Bay there was a drop in catch numbers during periods of pile driving for the port expansion. It was also anecdotally stated that wave noise affects catch numbers. No fish are caught during storm events, although they tend to return after a couple of days when the seas have calmed. This is thought to be caused by noise and sand in gills causing them to avoid the area.

5. It was also noted that fish are still landed when routine vessel noise occurs – Scrabster as a case in point – and that the acoustic output from the pile drilling approach likely in PFOW is less than that typically emanating from vessels

6. It was confirmed that fish are accustomed to high and variable background noise conditions. However, it was noted that human-originated noise had different characteristics

7. It was noted that the construction phase of projects was possibly of most concern to stakeholders – but note also Text Box 3.

2.2.10 **Question:** Do tags record the depth profile, and if not what monitoring methods can be used? How long do tags stay on the fish and are they of any use without GPS?

Responses:

1. Tags can be pre-set for a specific release time. Other options include: acoustic trackers (difficult in the Pentland Firth area), listening buoys and vessel tracking.

2. The possibility of following tagged smolts acoustically was discussed, and whilst it is possible to follow smolts in small boats in freshwater, it is more difficult / dangerous at sea.

3. It was noted that lines of hydrophones in river mouths provide information on timings of migrations.

4. Transponding tags were a possible option

5. It was noted that there was a view expressed to the workshop that the hydrophones that form the sensor arrays would be difficult to install in high energy areas such as the Pentland Firth, but that once tidal energy devices were in place, these could form platforms to deploy sensors (**Note**: cross reference with J. Armstrong presentation). It was noted that this whole issue needs to be looked at seriously, and that we need to **"get on with it",** by organisations working together

6. It was noted that much of this is about prioritisation: identifying immediate actions that need to be addressed now. What actions are most important and what is deliverable within available (limited) means / resources?

A3 Group working sessions

Part A3 of this Appendix covers the two group working sessions. The DP questions are copied here, and a non-attributable summary of each group's discussions / conclusions are presented thereafter. There has been no possibility of objectively 'scoring' group feedback on specific topics, and for the purposes of brevity, repetitions of issues common to groups is avoided as much as possible. However, where a specific issue is very common across groups, this is noted ('common'). The authors have reported topics as they emerged in the different group sessions, and whilst some of these might not seem appropriate or relevant for the question being posed, they have been retained in their original location. The authors have reported all comments that were recorded but are not able or willing to comment critically upon the accuracy or meaning of individual comments. **Opinions expressed by delegates and recorded in this report should not necessarily be considered to be factual.**

It was considered important to retain all participants' inputs on an impartial basis in this section of the report. Collation of comments into key blocks of main feedback has been undertaken in Section B, Chapter 8 of this report.

3.1 Question 1

On the basis of the evidence presented and your own knowledge and experience, which of the potential interaction-types are of most relevance or importance for: a) Wave energy? b) Tidal energy?
Group Feedback
A. Wave • Recognised that there are different types of wave technologies, and some interaction types may be more or less relevant to each (common) • Obstruction / Encounters (common) • EMF - from some devices, possibly seen as significant by some groups (common) • Noise – seen as significant by most groups • Requirement for arrays to be designed to minimize effects • Cables – horizontal directional drilling (HDD) to mitigate impact • Need to establish acoustic signatures, both during construction and of operational devices • Noted that technology changes with time e.g. higher capacity devices would mean fewer devices are deployed for the same overall capacity • Collision is a much lower risk than for tidal • Location of the device in relation to location of the fish (common) • Collision and barriers not seen as a priority by some delegates – although have to think about

cumulative effects

- Construction noise (but note Text Box 3)

B. Tidal

- Strike/Collision – (commonly mentioned, and one group said it represented the greatest risk)
- Risk to smolts (common)
- EMF (common)
- Noise (particle motion as well) - operational noise and construction noise (common)
- Noise and EMF lower perceived risk than collision

C). General

Lack of overall data to rule out any one of the possible risks

Cumulative Impact – effect of arrays of devices

PFOW is noisy, but manmade signatures are different. However, vessels are not regulated and wave and tidal stream developments are – disproportionate?

Location: are devices where the fish are? (common)

Uncertainty about deployment timescale

3.2 Question 2

a) Are any workshop delegates aware of additional knowledge in any of the topics that are not apparently being utilised at this time – e.g. knowledge about salmonid movements / presence in specific areas?

b) Given our current state of baseline knowledge, could the workshop make recommendations as to what should be expected from developers in their Environmental Statements and submission of data for Habitats Regulations Appraisal (HRA) / Appropriate Assessment (AA)?

Group Feedback

a) Additional sources of as-yet untapped information

- Tracking experience in the past: any information available from that work?
- Acoustics knowledge exists – is there an expertise gap?
- Biological response to noise
- Anecdotal evidence, local knowledge – generic (common)
- MS has already captured the majority of evidence
- It’s a scale issue – a fine scale is required
- Fish returning later; changing patterns e.g. herring

- Local knowledge and fishermen – has this been tapped into? (common)
- International research, case studies, etc.
- Other industrial development (e.g. oil and gas industry, aquaculture, wind turbines, etc.)
- Challenge of engagement with these 'sources'
- Datasets with limited public access
- **BUT NOTHING GAME CHANGING (Summary view)**

b) Expectation for developer input to EIA etc.

- Close liaison with stakeholders
- What is it reasonable for a developer to supply was raised as a valid question
- Can work out issues at a government level – not appropriate to ask developer to get all information
- Impact of climate change on populations – longer-term trends
- Wider international picture required
- EIA has a local context – what are the issues for the specific site?
- Regulator needs to determine what level of 'loss' is acceptable in relation to maintaining integrity of Natura 2000 sites
- 3-5% caught in nets; total annual take (rods and nets) of 40,000 fish from a returning stock of about 500,000
- Complex genetics of salmon
    - Consider in EIA
    - Difficult to consider impact of development on genetics of populations
- Impact on Sandeel harvest, birds / fish (*a wider issue*)
- Key is impact on genetic types (stock components) within the population
- A balance between expectations and the absolute legal requirement in terms of EIA preparation
- What is the REALITY:
    - How much information is out there?
- Who can perform the required research?
- Is there a pathway for interaction?
- Collective consideration of key questions
- Everyone to contribute to research funding
- Decisions made with some uncertainties
- Timeframes for answering questions in time for development build-out
- Licensing conditions are key, but must be measureable
- Robust licensing that is relaxed as more information is gathered
- Issues between regulators and developers getting appropriate advice / guidance / answers:

- Adaptive management
- Risks to developers

- Scale / location of project

3.3 Question 3

a) Is it reasonable to differentiate between different projects using different types of wave and tidal energy devices and proposed for location in different areas, in relation to requests for information during EIA / HRA / AA, and in relation to assessment during consenting decision-making?

b) If the workshop agrees this to be the case, could it make specific recommendations?

Group Feedback

a) Treat each project as different in EIA Scoping?

- Yes (common – all groups agreed)
- Tailored to individual site and/or technology (impact, risk, etc.)
- Companies have different technologies in different locations in PFOW
- Where are the fish? – regional / local distributions

b) Specific recommendations

- Endorse the Survey – Deploy – Monitor approach
    - But migratory fish issues not sufficiently covered in the guidance
- Focus on local specific issues e.g.:
    - Designations
    - Proximity to habitats etc.
    - Technical issues
- Proportion of information:
    - Technology
    - Scale
    - Location
    - Risk

3.4 Question 4

Can workshop delegates advise on whether any categories of 'knowledge gap' have not yet been fully identified and discussed, and do they have any recommendations about prioritisation of

knowledge gaps as a whole**?**
Group Feedback ***Editor's note:*** *the propensity for already-discussed knowledge gaps to be repeated in this section has been recorded, because it reflects the seriousness of the issue for some groups.*
• Prey of salmonids at sea • Preferred areas for foraging + prey + smolts etc. • Implications of acoustic masking • Salmon movements, local distribution, where in the water column, adults and juveniles (very common) • Establish significance of loss of population – SAC issue • Need to populate models with field data • Scaling effects of technical results • Basic behavioural observations of fish around types of devices (common) • Sea trout • Interactions: capacity to avoid / evade / detect turbines • Response to EMF and noise • **Where are migratory salmonids in relation to proposed deployment sites? (Location of the fish)** • Pathways for interaction • Smolts are a key issue (quite common) • Site specific Pentland data

3.5 Question 5

What are your thoughts on knowledge acquisition <u>priorities</u>, taking into account what is currently taking place and those in the planning stages?
Group Feedback

• Spatial overlap with intended arrays (+ migratory routes)
  ○ Paths
  ○ Water column spread
  ○ Functional overlap e.g. noise?
• Behavioural interactions

- Where are smolts and adults (spatial, temporal, depth etc.)
- Small scale – fluid dynamics modelling

Location of fish

Transferrable work from offshore wind?

- What are the technologies
- What do they cost
- What can they do
- Who will pay for them

Scoping of research/knowledge acquisition

- Swimming depths
- Behaviour in water column
- Smolt behaviour / locations
- (Out to sea or hugging coast. Curtains either side of river mouth)

3.6 Question 6

What are your recommendations on the steps that need to be taken to ensure the 'start small scale' opportunity is effective in the long term?

Group Feedback

- Scottish Government demonstration strategy
- EMEC: noise research (implication is that more information could come from EMEC projects)
- Select appropriate technology and location
- Need to be reasonably sure small scale will not have significant impact
- Gaps in development timetable need to be used wisely (enough power from monitoring)
- Need good baselines before starting
- Need effective monitoring technology (fit for purpose) (SNH group on technology)
- Funding of monitoring devices on early projects is an issue – too much to expect developers to do it alone
- First small scale deployments should be at sites with potentially high interaction – gives scope for meaningful studies
- Need understanding of the scaling of sites / developments: likely to be non-linear, as dictated by construction issues
- Need maximum learning from EMEC (and see above. Is there a need for EMEC2?)
- Decommissioning cutouts if significant negative impacts are observed:

- Risk?
- Financial viability?
- Robust and rigorous monitoring
- Dependent on licensing conditions
- Runaway train?
- Size scaling not always relevant – for example cabling
- Phase I monitoring:
    - What is transferrable to Phase II
    - If a fish passes through a turbine, OK, how can we measure consequence or behaviour effect
    - Migratory fish cannot be directly compared with habituated fish

3.7 Question 7

The Discussion Paper supports / encourages the further development of encounter modelling for salmonids. What are your views on putting additional resources into developing improved encounter models?

Group Feedback

- Yes more resource needed, but do not spend money on improving models – the models are often already adequate, what is needed is better data to feed into them (very common)
- Link to particle tracking model
- Improve biological input assumptions
- Fish behaviour – coastal following
- Validation (common)
- Models need to differentiate adults and juveniles
- Parameterisation / groundtruthing (common)
- Do we need models for wave devices?
- How realistic are the model assumptions:
    - Biological
    - Depth
- WHERE ARE THE FISH?

3.8 Question 8

As knowledge of the presence or absence of migratory salmonids at specific locations improves, and as modelling techniques become increasingly evidence-based in terms of assumptions, the ability to conduct Cumulative Impact Assessments (CIA)s for projects will improve. Bearing in mind the current state of baseline knowledge, and the steps being taken to acquire new knowledge and bridge knowledge gaps, what recommendations could you make about how the CIA process should be applied in respect of the PFOW projects and migratory salmonids at this point in time?
Group Feedback
• Types of cut-off, timescale, information level – guidance is required • Work on this is ongoing (The Crown Estate, etc.) • Potential for SEA to include assessment of capacity for development • Regional marine planning • Specify time limits for projects in CIA • Marine Scotland will identify projects to be included in CIA (reasonably foreseeable – scoped) • Problem of data/information availability • Some sites more sensitive for salmonids than others • The Precautionary Principle applies • A general issue, not different for salmon – may need to include other non-marine activities e.g. freshwater life phases of salmon • Developers unsure of definitive technologies / timeframes • WHERE ARE THE FISH? • Regulators and developers will struggle • PBR (potential biological removal), taking into account existing pressures on the population

3.9 Question 9

Are there any other issues or topics, not already covered, that you would like the workshop plenary or sub-groups to discuss**?**
Group Feedback
• Reconstituted Boards should be constituted to manage stocks effectively • Better links and co-ordination between MSS; DSFBs; Fisheries Trusts • Sufficient funding

- Wave and tidal version of ORJIP?
- If decline in populations occur then need mechanisms for enhancement? (Problem of cause and effect)
- Mitigation or removal?
- Must not lose momentum
- Continue the discussion
- The importance of smolts
- Sea trout
    - Continual presence
    - Same issues of lack of knowledge
    - Some reports exist (Orkney)
- What will we do if research says there will be an effect – clarity required
- What precedents have been set by other sectors

A4 Closing discussions and statements

4.1 Final Plenary Discussion

4.1.1 Importance of smolts and knowing where they are

The importance of the potential for impacts on smolts seemed to be a thread through much of the workshop, and the importance of understanding more about their behaviour and specific locations was stressed by several groups and individual delegates. When the workshop plenary was asked for a show of hands as to whether this was the most important topic, it was interesting to note that there was only a partial agreement. There is a view that 95% or more of smolts die at sea anyway, and that it is returning adults that are scarce and valuable.

4.1.2 Consultation on assigning AfLs

A lack of consultation by The Crown Estate in the process of awarding the AfLs in the PFOW area was raised. There was also concern regarding the impact of deployments on creel fishers – those impacted off Orkney may start to fish off Caithness instead, leading to the potential for over-fishing and confrontation between fishermen.

Responses:

1. Future consultation by The Crown Estate needs to be at a much earlier stage and more wide ranging, but there is a limit to what The Crown Estate is able to do.
2. It was also noted that award of future wave and tidal sites will be in line / conjunction with the developing wave and tidal sectoral plans and that communication channels are 'opening-up' through the Marine Spatial Planning process.
3. It was stressed that the actual areas of sea that would finally be developed in the PFOW area will be much smaller than the AfL 'boxes on maps', and that part of the problem has been poor initial explanation of this, including in the media (which would have been better explained in a process of earlier consultation). AfL areas are 'areas of search' only. The Crown Estate is aware of the fisheries issue, and a 'spatial interaction project' is underway in Orkney and Caithness.
4. The final lease areas will be contingent on the consenting process. The Crown Estate will only enter into leases with developers once all of the statutory consents and permits have been obtained.

4.2 Closing Remarks by The Crown Estate

1. There had been excellent input into the workshop.
2. Tony Hawkins, the project team and all speakers and delegates were warmly thanked.

3. The workshop and Discussion Paper project was funded through the Enabling Actions Programme, and was instigated at the request of three Caithness developers. It is hoped that this project demonstrates that The Crown Estate and the PFOW developers are committed to look at all of these issues in a robust fashion.

4. In terms of next steps:

- A Workshop Report will be prepared
- The Discussion Paper will be updated.

4.3 Chairman's Summary

The Chairman briefly summarised his thoughts:

1. He considered the event to be very successful
2. The primary need is to know where the fish are, and how they behave
3. Noise and EMF were raised as particular concerns
4. There was strong agreement on priorities
5. Key question – how do we bring this about, and fund? Co-ordination of funding?
6. He highlighted need for wider feedback to communities
7. He raised the possibility of smaller group meetings in the future to consider, for example, movement of fish
8. The Chairman thanked all concerned.

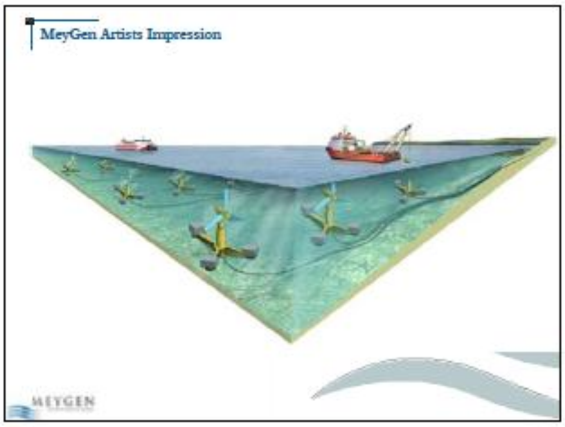
Appendix 2 Workshop delegates

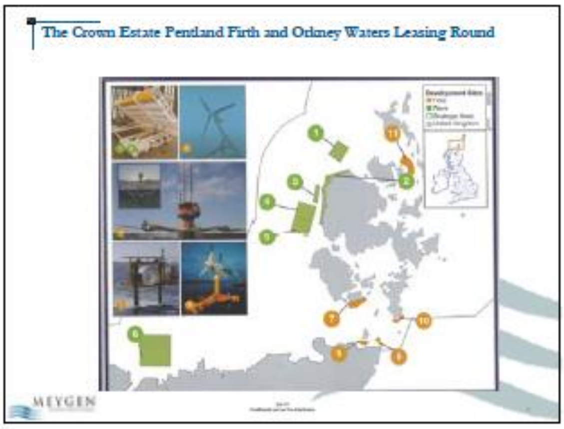
Name	Organisation
Tony Hawkins	Workshop Chair
Mike Cowling	The Crown Estate
Toby Gethin	The Crown Estate
Richard Slaski	Epsilon Resource Management
Darren Hirst	Epsilon Resource Management
Sandra Gray	Epsilon Resource Management
Ed Rollings	MeyGen **(Speaker)**
Laura Carse	Pelamis **(Speaker)**
Richard Morris	SPR
Marten Meynell	Aquamarine
Robin Burnett	SSE
Shane Quill	OpenHydro
Cara Donovan	MCT
Chris Higham	E-On
Donna-Claire Hunter	Independent observer
William Harris	MS Orkney
Ian Davies	MSS Marine Renewable Energy Programme Manager **(Speaker)**
Tracy McCollin	MS Planning and Policy
Roger May	MS LOT **(Speaker)**
John Armstrong	MSS FWL **(Speaker)**
Iain Malcolm	MSS FWL
Angus Jackson	ERI **(Speaker)**
George Lees	SNH
Chris Eastham	SNH
Colin Bean	SNH
James Green	Orkney Islands Council
Shona Turnbull	Highland Council
Alan Wells	ASFB **(Speaker)**
Keith Williams	Ness & Beauly Fisheries Trust
James MacKay	Armadale Salmon Fishing & SNFAS
Alan Youngson	Caithness DSFB
Crispian Cook	Northern DSFB

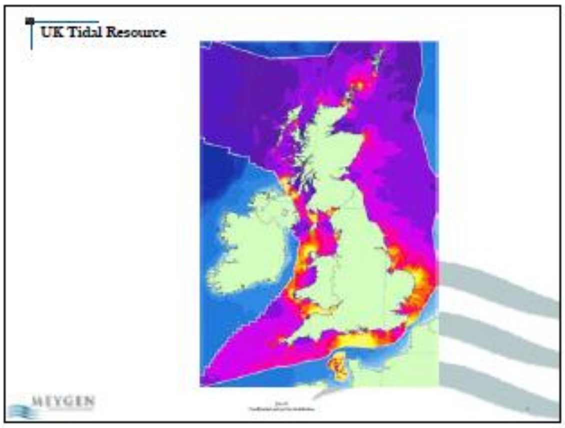
Shona Marshall	West Sutherland Fisheries Trust
Alastair Stephen	SSE / Institute of Fisheries Management
Chris Conroy	River Naver Superintendent
Adam Payne	Xodus
Jen Trendall	Royal Haskoning
Ross Gardiner	MSS FWL
Peter Quail	Helmsdale River Superintendent
William Grant	Halladale River Superintendent

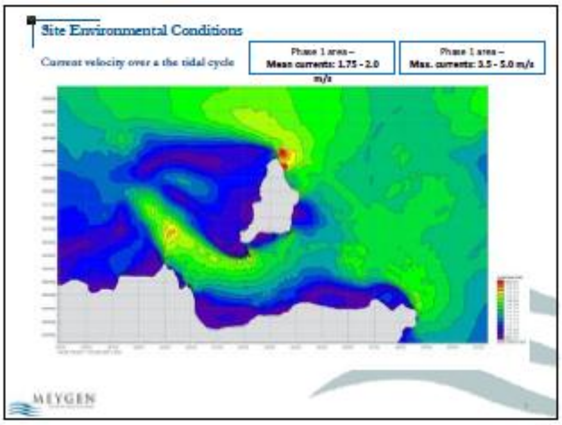
Appendix 3 Workshop presentations

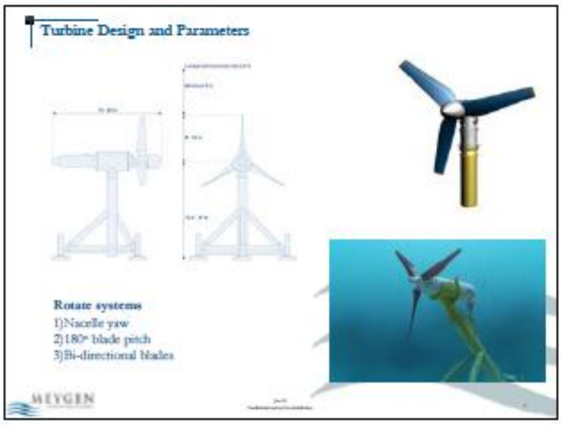
Appendix 3 a. Ed Rollings, Meygen Ltd

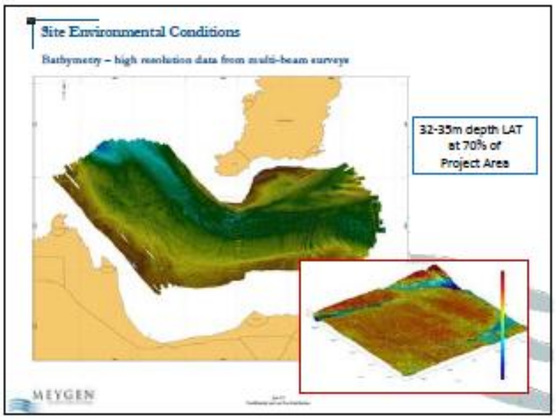


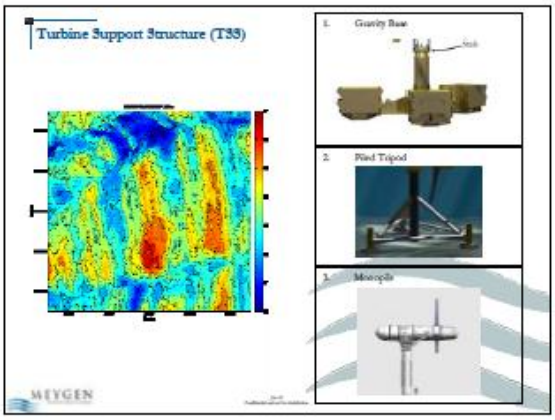


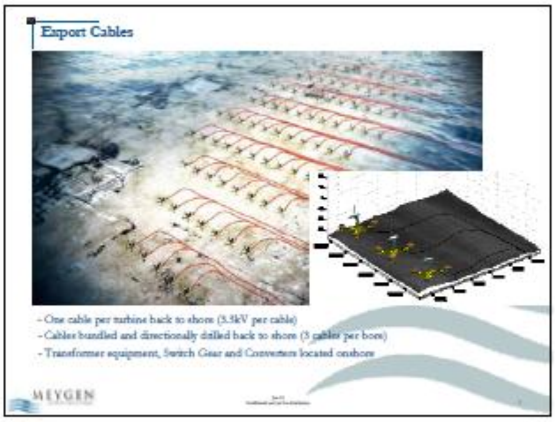




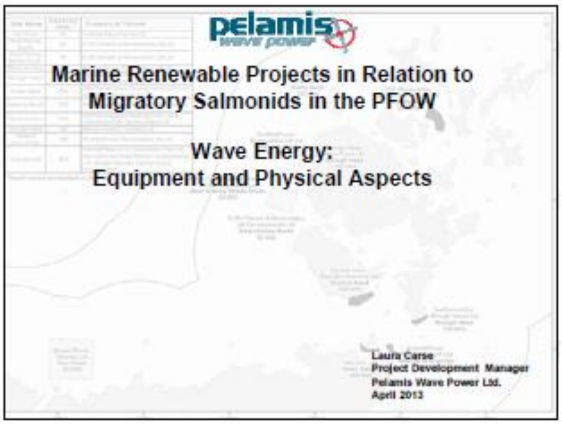


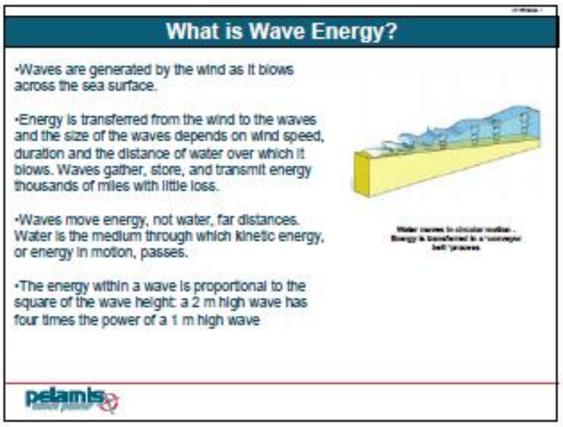

Site Environmental Conditions
Bathymetry – high resolution data from multi-beam surveys
32-35m depth LAT at 70% of Project Area
MEYGEN

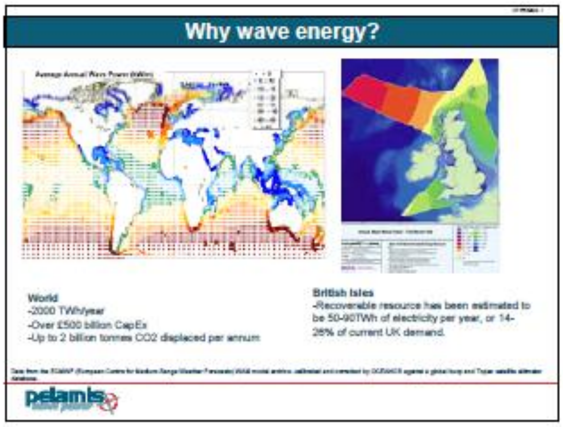

Turbine Support Structure (TSS)
1. Gravity Base
2. Piled Tripod
3. Monopile
MEYGEN

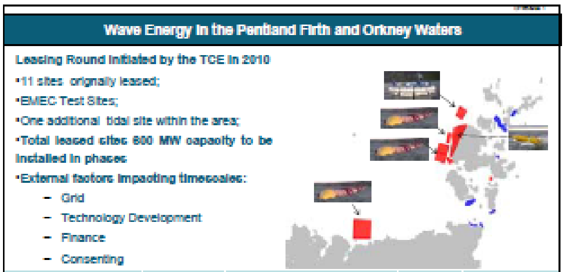

Export Cables
- One cable per turbine back to shore (3.3kV per cable)
- Cables bundled and directionally drilled back to shore (3 cables per bore)
- Transformer equipment, Switch Gear and Converters located onshore
MEYGEN

Appendix 3 b. Laura Carse, Pelamis Wave Power Ltd

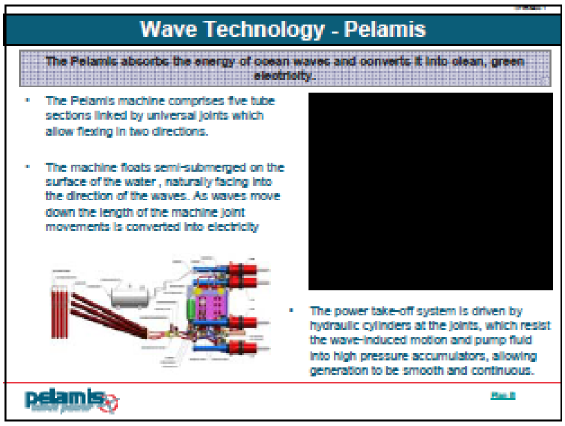




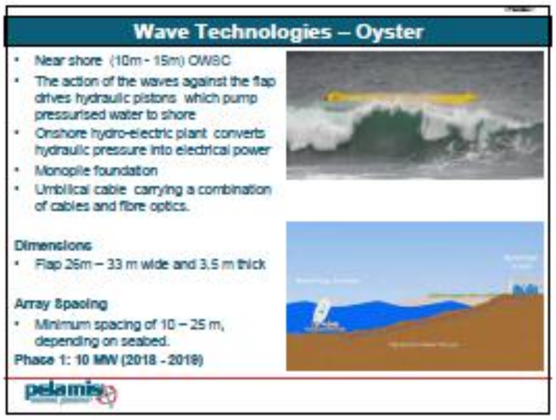


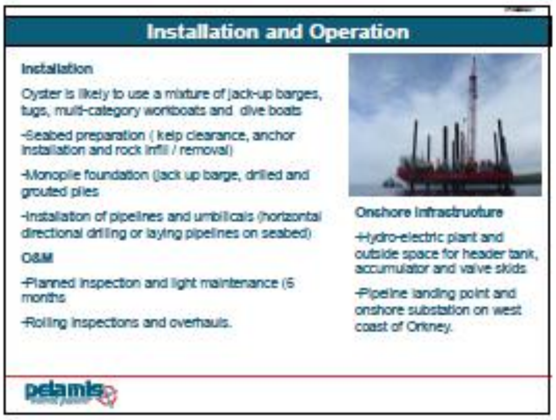


Site	Technology	Developer	Phase 1 (MW)	Total Leased (MW)
Farr Point	Pelamis	Pelamis	10	50
Marwick Head	Pelamis	SPR	9	50
Costa Head	AWS	Alstom & SSE	10	200
Brough Head	Oyster	Aquamarine & SSE	10	200
West Orkney South	Pelamis	EON	10	50
West Orkney M South	TBC	EON	10	50




Installation and Operation
Installation
Multi category workboats and tugs to lay moorings and install machines.
Specialised cable laying vessels for subsea cables.
Onshore shore infrastructure will include substation, transition box and grid connection
Remote control from local office or Leith
Operation and Maintenance
Machines currently undergoing a 'work up plan' to define O&M schedule
Removal from site and tow back to local O&M base
Parr Point: (Phase 1) 7.5 – 10 MW 2016
Marwick Head (Phase 1) - 9 MW 2019
WOMS (Phase 1) – 10 MW 2018?
pelamis
7


Wave Technologies – Oyster
Near shore (10m - 15m) OWSC
The action of the waves against the flap drives hydraulic pistons which pump pressurised water to shore
Onshore hydro-electric plant converts hydraulic pressure into electrical power
Monopile foundation
Umbilical cable carrying a combination of cables and fibre optics.
Dimensions
Flap 26m – 33 m wide and 3.5 m thick
Array Spacing
Minimum spacing of 10 – 25 m, depending on seabed.
Phase 1: 10 MW (2018 - 2019)
pelamis


Installation and Operation
Installation
Oyster is likely to use a mixture of jack-up barges, tugs, multi-category workboats and dive boats
-Seabed preparation (kelp clearance, anchor installation and rock infill / removal)
-Monopile foundation (jack up barge, drilled and grouted piles
-Installation of pipelines and umbilicals (horizontal directional drilling or laying pipelines on seabed)
O&M
-Planned inspection and light maintenance (6 months
-Rolling inspections and overhauls.
Onshore Infrastructure
-Hydro-electric plant and outside space for header tank, accumulator and valve skids
-Pipeline landing point and onshore substation on west coast of Orkney.
pelamis


Wave Technologies – AWS-III
Offshore Point Absorber
Multi cell of flexible membrane absorbers
Converts wave power to pneumatic power through compression of air within each cell
Turbine generators convert pneumatic power to electricity
Each machine rated at 2MW
Inter array cabling export at 11 – 33Kv, future potential for offshore substation
Dimensions
Each machine has 12 cells (16 m x 8 m) around a circular structure
Total diameter 60 m
Array Spacing
Phase 1: 10MW (four AWS-III)
Based on mooring configuration, a five device array will occupy 1.6 km²
SSE
ALSTOM
pelamis


AWS – III: Installation and Operation
Installation
•Final assembly at a local port, followed by tow out by ocean-going tug(s).
•Specialised cable laying vessels to installed subsea cables. Cables potentially buried or protected by concrete mattresses /rock dumping.
•Installation (Phase 1) 2015 – 2016
O&M
•Periodic overhauls (5 years), potentially requiring unit removal.
•In situ scheduled maintenance
•Unscheduled maintenance assisted by a support vessel.
pelamis


PROJECT DEVELOPMENT: Ongoing Activities
Resource Assessment
-Wave Rider Buoys and ADCPs
-Deployment, O&M, Data Analysis
Grid and Electrical
-Modelling, Design and Integration
Environment and Consenting
-EIA and HRA
-Navigation and Fisheries
-Consultations
Geophysical Survey
-Bathymetry & Sub Bottom Profiling
-Geotechnical Survey
Academic Collaborations
-Environmental Research
-Resource Assessment
Land Leases
- Onshore cable routes
Supply Chain
- Analysis and Delivery
pelamis

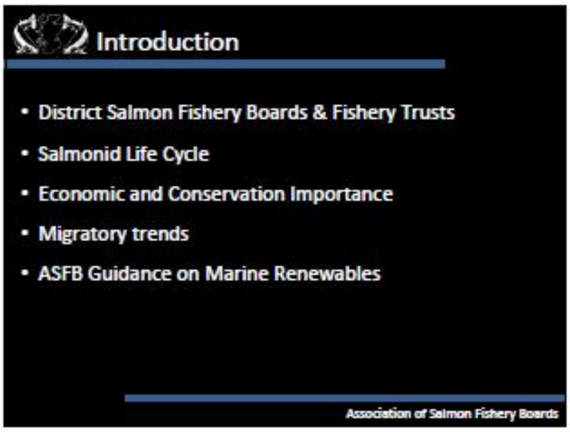
Summary Remarks

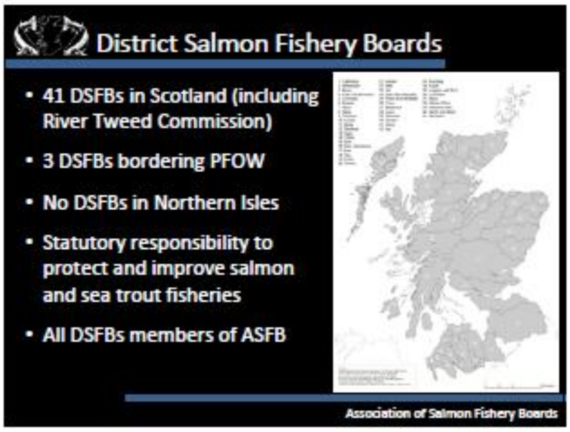
- Range of technically disparate wave energy technologies planned for deployment occupying a range of locations from the nearshore to the offshore area.
- Some technologies do not generate electricity at sea.
- 600 MW of sites have been leased but development will be phased, driven mainly by financial, grid and technological constraints.
- Leased areas shown on strategic planning documents show ' areas of exclusivity' only, sites are likely to occupy small areas within these zones.
- First phase developments unlikely to exceed 10MW (equivalent to 4 wind turbines at Causeymire)
- Cable landing points yet to be defined and agreed.
- Timescales for installation post 2016, but may be impacted by wider transmission network upgrades between the mainland and Orkney Islands.
- Project development activities ongoing, but include offshore surveying.

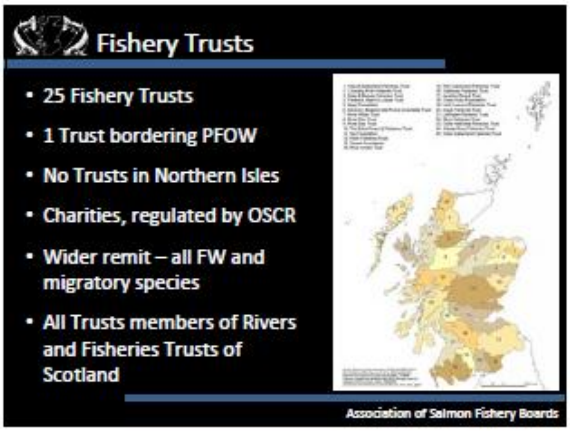
Finally, the context and scale of marine renewables has to be considered in light of other activities within the marine environment:

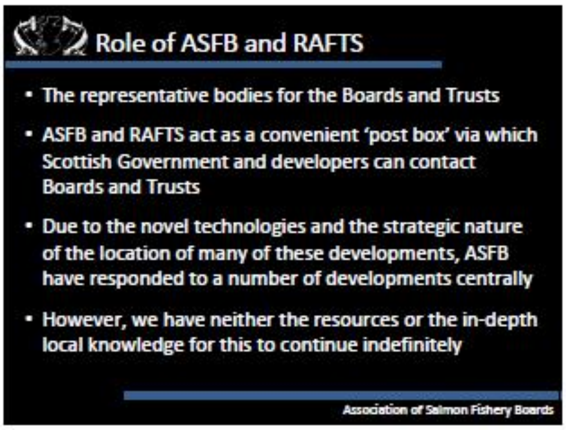
Shipping and Ferries	Subsea Cables and Pipelines	Telecommunications
Port and harbours	Aquaculture	Fishing
Farming	Onshore Developments	Oil and Gas Developments
Yachting	Military	Dredging

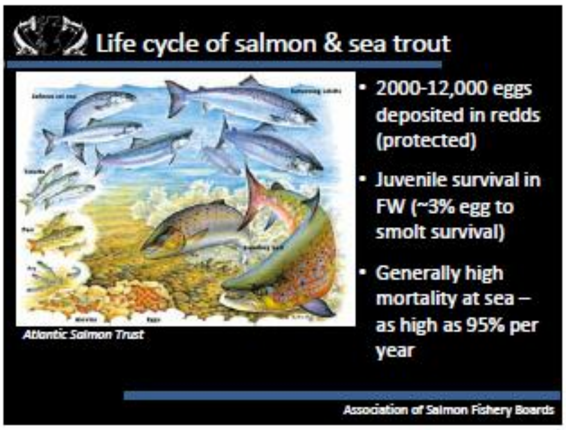
Appendix 3 c. Alan Wells, Association of Salmon Fishery Boards











Economic Importance

- 2004 analysis - over £100 million worth of annual output, supporting around 2,800 jobs and generating nearly £50million in wages and self-employment into Scottish households.
- Significant commercial fisheries (incl PFOW)
- Spring, Summer & Autumn Salmon (salmon vs grilse)
- Loss of a stock component is the difference between full time and part time employment

Association of Salmon Fishery Boards

Conservation Importance

- Atlantic salmon and sea trout are also of significant conservation importance
- 17 SACs for Atlantic salmon
- 15 at unfavourable status
- Marine phase of both species are Priority Marine Features – the habitats and species of greatest conservation importance in inshore waters

Malcolm et al. (2010)

Association of Salmon Fishery Boards

Atlantic Salmon SACs

Status of SAC rivers analysed in 2010 (MSS)

Spring
- 94% declining (15 of 16 rivers)
- 0% increasing (0 of 16 rivers)
- 6% stable (1 of 16 rivers)

Summer
- 19% declining (3 of 16 rivers)
- 72% increasing (10 of 16 rivers)
- 19% stable (3 of 16 rivers)

Autumn
- 6% declining (1 of 16 rivers)
- 82% increasing (13 of 16 rivers)
- 12% stable (2 of 16 rivers)

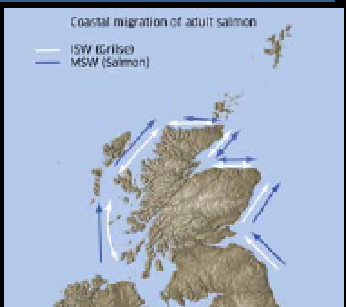
Association of Salmon Fishery Boards

Migratory Trends - Salmon

Atlantic Salmon Federation

Association of Salmon Fishery Boards

Migratory Trends - Salmon



Malcolm et al. (2010) Scottish Marine and Freshwater Science Vol 1 No 14

Association of Salmon Fishery Boards

Migratory Trends - Salmon

- Studies from Norway indicate that post-smolts travel rapidly out of fjord areas, generally at shallow depths
- Coastal migration patterns by Scottish post-smolts is unknown, although high densities of post-smolts have been observed off the west and north west coasts of Scotland
- Fish return to the Scottish coast from a range of directions, with a northerly and westerly bias
- Pentland Firth of potential strategic importance

Association of Salmon Fishery Boards

Migratory Trends - Salmon

- On reaching the Scottish coast salmon subsequently migrate towards their natal river. Apparently variable and random directions of movement for a given location
- Adults appear to spend most of their time in shallow water (generally 0-40m), although they can dive to substantial depths up to 280m
- Swimming depths of adult fish in Scottish coastal waters remain unknown, but it could be highly variable

Association of Salmon Fishery Boards

Migratory Trends – Sea Trout

- Do not migrate rapidly out to sea from inshore coastal areas
- Tend to use near shore sea loch and fjord areas where available - uncertain what happens to sea trout smolts on the east coast where no such areas exist
- Considerable uncertainty as to the movement of sea trout after the initial few months in the marine environment for both the west and east coasts of Scotland
- Little or no data on swimming depths

Association of Salmon Fishery Boards

Threats to Salmon and Sea Trout

Freshwater
- •Aquaculture
- •Climate Change
- •Degradation of Habitat
- •Hydro
- •NNIS
- •Over-exploitation
- •Pollution
- •Predation
- •Stocking (non-natives)

Coastal & Marine
- •Aquaculture
- •Bycatch
- •Climate Change
- •Degradation of Habitat
- •Over-exploitation
- •Pollution
- •Predation
- Marine Renewables?

Association of Salmon Fishery Boards

Threats to Salmon and Sea Trout

- Generally considered that the most significant threats are those in the marine environment
- It is clear that survival of salmon and sea trout during their marine migration phase has fallen over the last 40 years. Some of this reduced survival can be explained by changes in sea surface temperature and subsequent contraction of feeding grounds.
- Key strategy for managing adaptation of species sensitive to climate change, such as Atlantic salmon and sea trout, is to minimise *additional* man-made pressures

Association of Salmon Fishery Boards

Guidance to DSFBs & Trusts

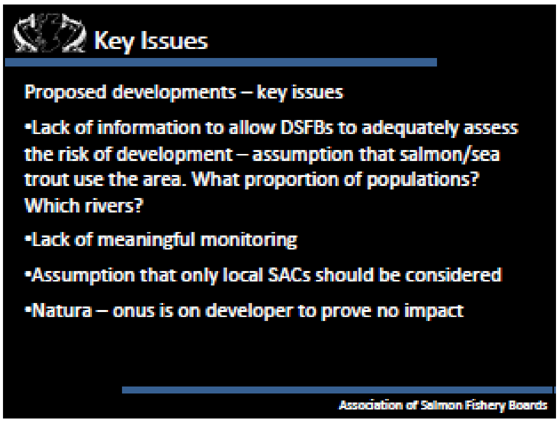
- Guidance for dealing with the planning process for offshore renewables developed in 2012
- Largely based on MSS Screening and Scoping Guidance
- Available at: http://www.asfb.org.uk/publications/

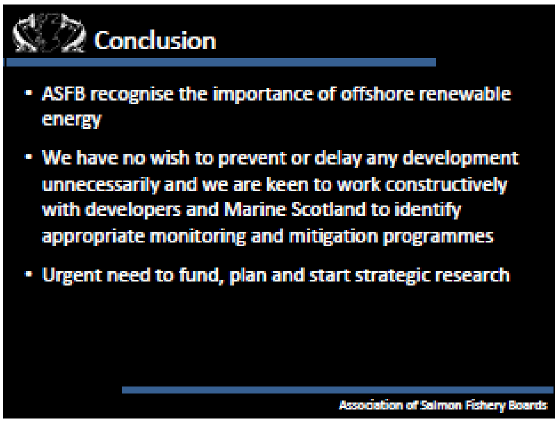
Association of Salmon Fishery Boards

Key Issues

- Subsea noise during construction
- Subsea noise during operation
- Electromagnetic fields (EMFs) arising from cabling
- EMFs arising from operation of devices
- Disturbance or degradation of the benthic environment (including secondary effects on prey species)
- Aggregation effects (associated aggregation of predators)
- Strike or cavitation effects (or effects resulting from barriers to migration)

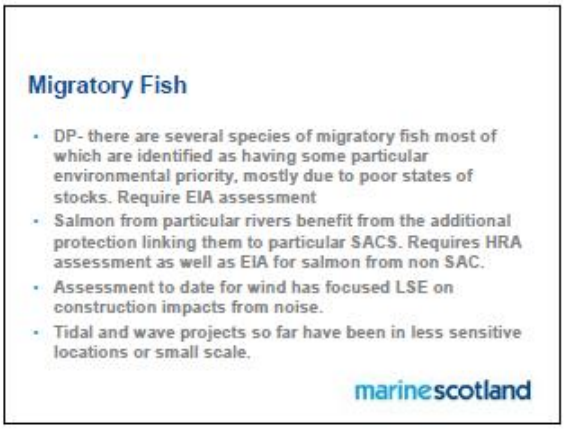
Association of Salmon Fishery Boards

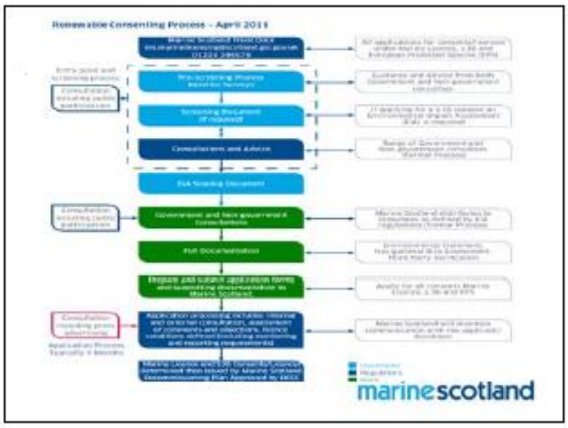

Key Issues
Proposed developments – key issues
•Lack of information to allow DSFBs to adequately assess the risk of development – assumption that salmon/sea trout use the area. What proportion of populations? Which rivers?
•Lack of meaningful monitoring
•Assumption that only local SACs should be considered
•Natura – onus is on developer to prove no impact
Association of Salmon Fishery Boards


Conclusion
• ASFB recognise the importance of offshore renewable energy
• We have no wish to prevent or delay any development unnecessarily and we are keen to work constructively with developers and Marine Scotland to identify appropriate monitoring and mitigation programmes
• Urgent need to fund, plan and start strategic research
Association of Salmon Fishery Boards


Contact details
Alan Wells
alan@asfb.org.uk
Tel: 0131 272 2797
Association of Salmon Fishery Boards

Appendix 3 d. Roger May, MSLOT





EIA/HRA

- The principle difference between EIA and HRA is that if impacts can not be determined for HRA a project should not proceed.
- There are currently projects which because of perceived connectivity and an unquantifiable level of impact are unconsentable under HRA.

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Policy

- A way forward is to allow phased deployment.
- Based on expert advice an initial phase is allowed to be deployed which under expert opinion will not cause adverse effects at the population level
- Again there may be locations where even this level of deployment is not consentable.
- Careful monitoring of the impacts is essential before allowing further deployments.
- Also allows gradual assessment of other impacts such as barrier effects.

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Summary

- Both consenting regimes S36 and Marine Licence require EIA for projects of the scale of PFOW. There are a number of potential impacts including EMF, noise and collision which need to be assessed.
- HRA will be necessary for Salmon (and by extension Fresh Water mussel where applicable) where LSE is identified.
- Knowledge base both on potential connectivity and real impacts is minimal.
- Current knowledge base makes consenting particularly with regards to HRA difficult
- Policy of phased deployment whilst gathering and assessing actual impacts is seen as the way forward.

marinescotland

end

- Contacts:-
- Marine Scotland – Licensing Operations Team
- Marine Laboratory PO Box 101
- 375 Victoria Road Aberdeen AB11 (DB
- Direct Line +44 (0)1224 285579
- Fax +44 (0) 1224295524
- ms.marinelicensing@scotland.gsi.gov.uk
- Web http://www.scotland.gov.uk/Topics/marine/Licensing/marine/Applications

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Appendix 3 e. Ian Davies, MSS

Interactions of salmonids with renewables devices, and licensing

The Scottish Government

Ian Davies

Marine Scotland Science

marinescotland science

Conservation of salmon

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Natura 2000

- EU designation and associated obligations
- Maintain population as viable component of the site
- LOT advised by SNCBs – SNH
- Disputes – Commission – infraction of Government

Fisheries

- Private/commercial interests
- Achieve conservations limits and increase harvest
- LOT advised by Boards/Trusts/Associations
- Disputes – Judicial review of licensing process
  - Between developer and private interests

Conservation of SAC populations

marinescotland science

HRA to assess potential impacts on protected sites and species

Salmon: Primary forms of interactions:

- Collision
- emf
- Noise

Logic models of interactions

marinescotland science

	Model step		Confidence	Comments
1	PFOW is a significant migration area for juvenile and adult salmon and sea trout	Very likely	High	Better for adults than for juveniles, and better for salmon than sea trout.
2	Migrating salmonids use the same geographical areas of sea as could be utilised for tidal turbines.	Very likely	Medium	Better for adults than for juveniles, and better for salmon than sea trout.
3	Salmonids using these areas form part of the qualifying interest of Natura 2000 sites...	Very likely	High-med	Precise areas used by fish from different rivers are not known
4	The numbers of salmonids using these areas are significant proportions of the populations in some Natura 2000 sites.	Likely	Medium.	Precise areas used by fish from different Natura sites are not known.

Logic model continued

marinescotland science

	Model step		Confidence	Comments
5	The migratory activities of the salmonids take them into the swept areas of turbines	Possible	Med./high	Avoidance behaviour?
6	Turbine blades collide with the fish	Likely	Med./high	Modelling approaches
7	Injuries caused are significant	Yes	?	Assumed
8	The numbers of fish so impacted are sufficiently large to adversely affect the relevant populations.		LOT to determine	Key question

Interaction models

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"Encounter models", e.g. Gerritson

- Models turbine blades as predators
- Fish as prey
- Mainly used for mammals to date

"Collision models", e.g Band

- Based on wind farms and birds
- Combines physics of collision with rotating turbines with biological factors.

Both require density (flux) of fish, and "avoidance rate".

Density/flux/distribution of fish

marinescotland science

No observational data on distribution of fish in PF.

Depth m	% of records
0 - 5	58.2
5 – 10	14.5
10 – 15	6.1
15 – 20	4.2
20 - 25	3.7
25 - 30	2.6
30 - 35	2.4
35 - 40	1.6
40 +	6.93

Holm et al, 2006

Norwegian Sea, 5 fish

Sturlaugsson, Iceland

Relocated fish. Mainly <4m depth

Rikardsen, Tromso

70 – 80% of time at 0 – 5 m

Probability of collision

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1 Observation in field

EMEC

East river etc

2 Expermental data

a) High proportion of fish can avoid turbines in flumes

b) 98.5%+ of fish passing through turbines survive

Band predicts about 80 – 85%

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marinescotland science

Use encounter rate or collision modelling to derive estimates of numbers or proportion of fish encountering or colliding with turbines.

Assuming that collisions result in mortality, are the additional mortalities significant?

Pre-fishery abundance : About 500,000

Annual harvest : About 40,000

Potential impact monitoring activities

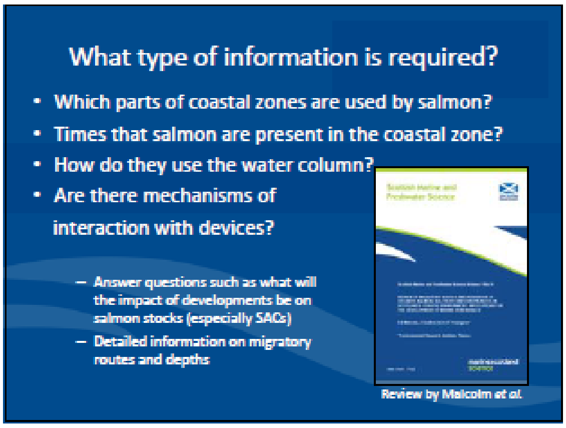
marinescotland science

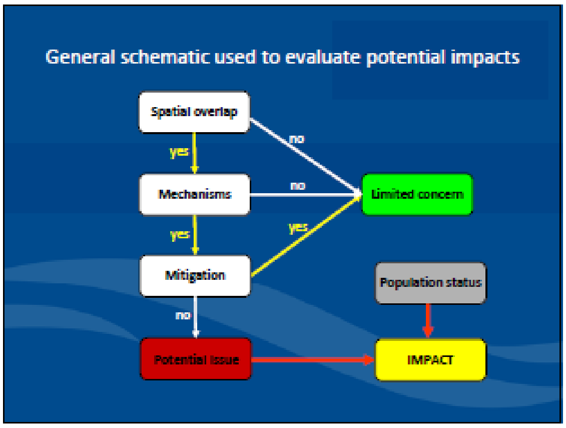
Monitor actual collisions with turbines
Confirm model predictions

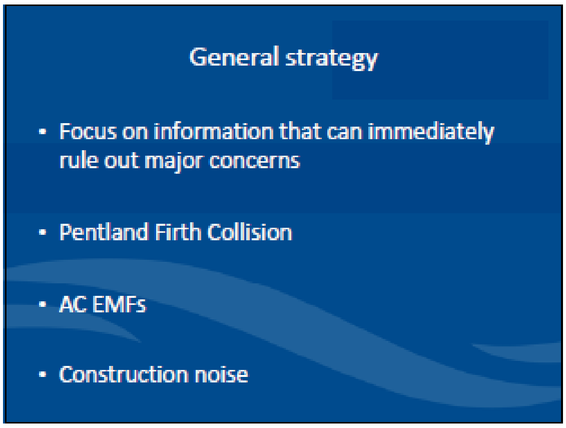
Monitor changes in conservation status
Catches — Data already gathered
Juvenile production — Electro-fishing
Smolt migration

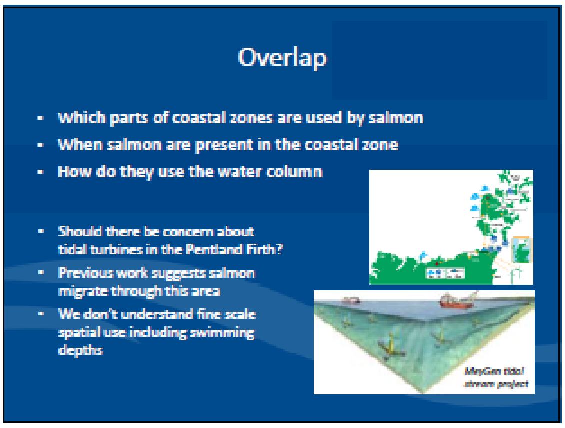
Monitor stocks directly
Install counters/traps on rivers
Feasibility, cost, reliability, technology, operation, etc

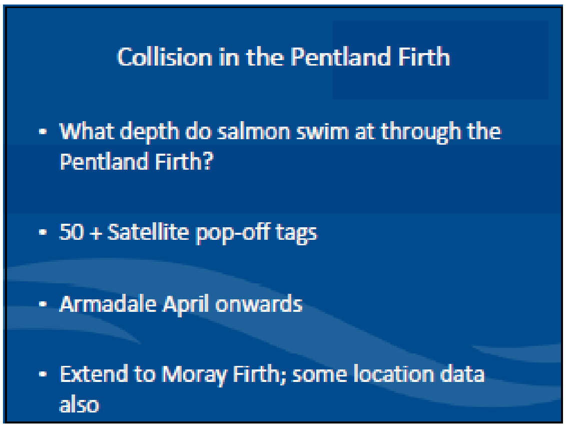
Appendix 3 f. John Armstrong, MSS





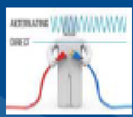






Electromagnetic Fields

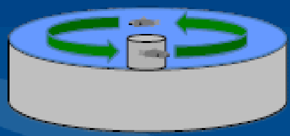
- SNH commissioned review by Gill *et al.* 2012 (Journal of Fish Biology 81, 664-695)
- Diadromous fish can use the Earth's magnetic field for direction and orientation during migration
- EMF from subsea cables may interact with migrating fish (especially eels)
- Not necessarily biologically important
- 2 types of EMF – AC and DC



Testing the response of salmon smolts to AC EMF

- Experimental work being undertaken in the tank facilities in Aberdeen
- Aim is to examine the effect of AC EMF fields on swimming behaviour

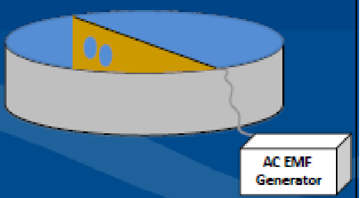
- Annular tank
- Salmon post-smolts swimming round tank
- Experiments also undertaken with silver eels



Tank diameter of 9.8 m

Experimental setup

- Tank partitioned into two sections
- Movements between different sides through 4 circular openings (2 on each side of the partition)
- The openings are connected to an AC EMF generator



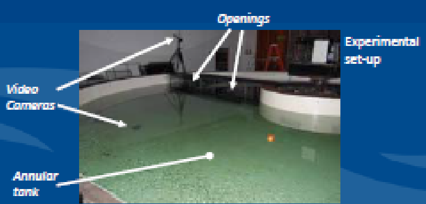
Experimental setup

- EMF generated in openings
- Range of field strengths can be produced

- How often do smolts go through the openings when the EMF field is present and when it is absent?
- Startle/avoidance response

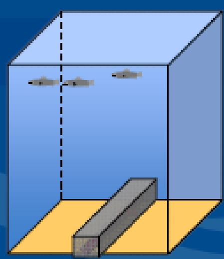
Progress

- 18 trials undertaken with salmon post-smolts
- 64 hours of camera footage studied
- trials also conducted using eels also underway



Mitigation: Electromagnetic Fields

- EMF levels drop off rapidly within a few meters away from the cables, animals need to be reasonably close in order to be impacted
- Potential impact of EMFS can be mitigated against by burying the cables
- Burying cables is costly, but is being considered for security reasons



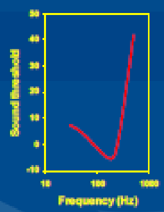
Mechanisms: Noise

- SNH commissioned review by Gill *et al.* 2012 (Journal of Fish Biology 81, 664-695)
- Paucity of information on noise generated by marine renewable developments
- Construction noise likely to be the most substantial
- Cumulative effects are possible
- Considerable uncertainty over the response of diadromous species to underwater noise

Mechanisms: Noise

MSS has commissioned a series of projects to:

1. Measure audiograms of salmon, sea trout and eels to improve understanding of their hearing
2. Assess the behavioural response of caged fish to noise associated with pile driving
3. Model the consequences of salmon exposure to piling and operational noise



Salmon audiogram
Hawkins & Johnstone 1978

Other Mechanisms

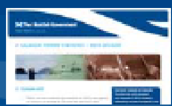
- "There are also unknown unknowns – there are things we do not know, we do not know"

  Donald Rumsfeld

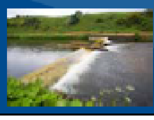
- There may be some mechanisms that may not be known at the moment which may impact on salmon populations
  - e.g. changes to predators/prey caused by renewables developments which have a knock-on effect for salmon populations
- How to deal with unknown unknowns?

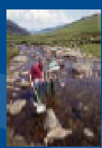
Monitoring of Populations

- One way to identify unknown mechanisms is to monitor the populations to see if there are any changes associated with renewable developments
- Three main type of data collected on salmon populations
  - Catches

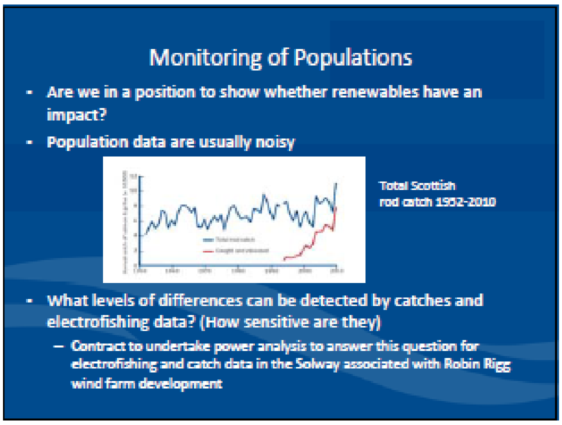


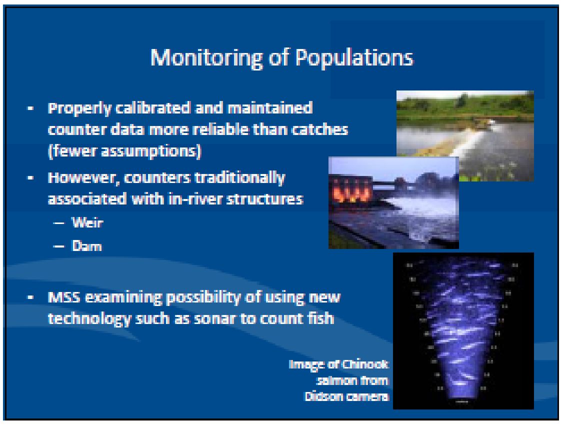
  - Counters

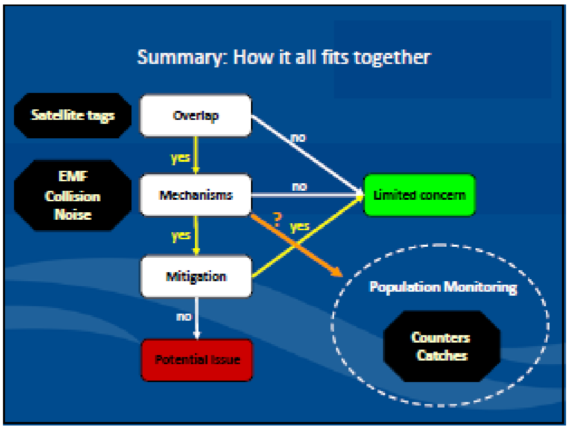




Electrofishing


Monitoring of Populations
• Are we in a position to show whether renewables have an impact?
• Population data are usually noisy
Total Scottish rod catch 1952-2010
• What levels of differences can be detected by catches and electrofishing data? (How sensitive are they)
– Contract to undertake power analysis to answer this question for electrofishing and catch data in the Solway associated with Robin Rigg wind farm development

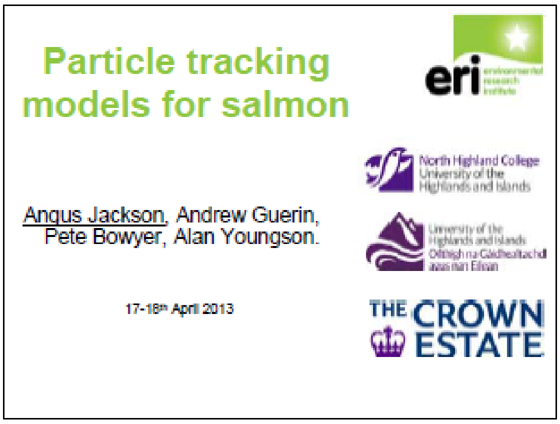

Monitoring of Populations
• Properly calibrated and maintained counter data more reliable than catches (fewer assumptions)
• However, counters traditionally associated with in-river structures
– Weir
– Dam
• MSS examining possibility of using new technology such as sonar to count fish
Image of Chinook salmon from Didson camera

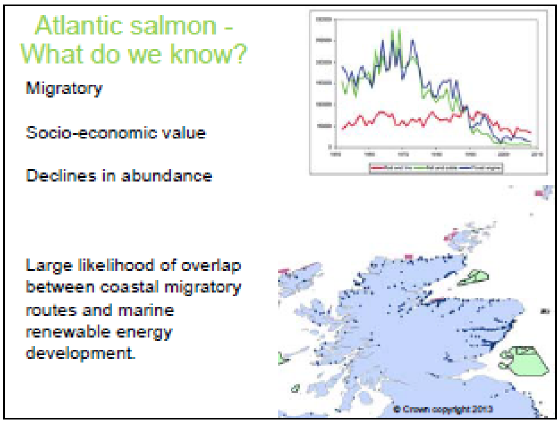

Summary: How it all fits together
Satellite tags
EMF
Collision
Noise
Overlap
Mechanisms
Mitigation
Potential issue
Limited concern
Population Monitoring
Counters
Catches
yes
yes
no
no
no
?
yes

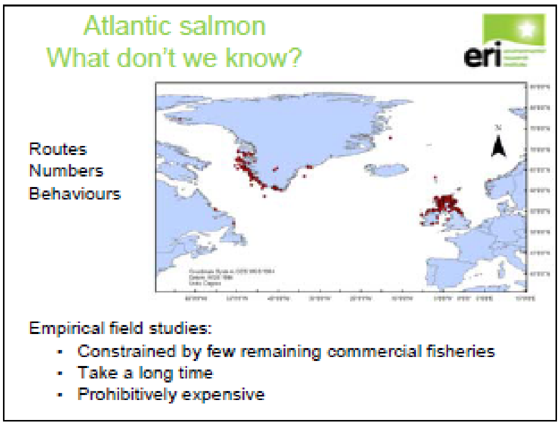

Next steps – scoping (subject to consultation)
• Coastal migration routes - acoustic arrays
• Near-river behaviour - acoustic tracking arrays
• Scottish fish counter network – conservation limits and stock status
• Map of post-smolt distribution in North Sea

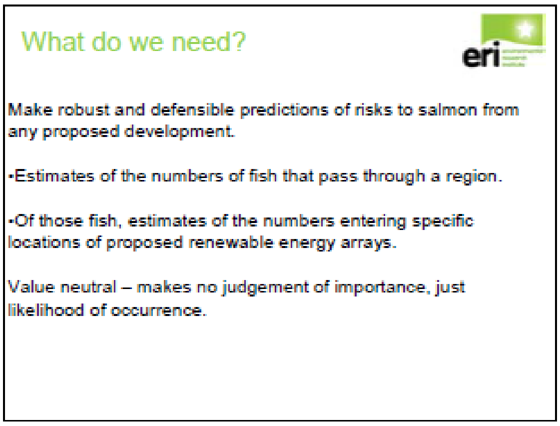

Post-deployment (subject to consultation)
• Acoustic tracking arrays on generators
• Acoustic cameras on generators

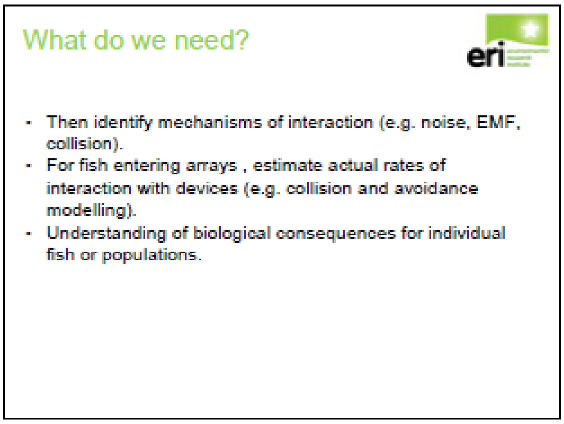
Appendix 3 g. Angus Jackson, ER

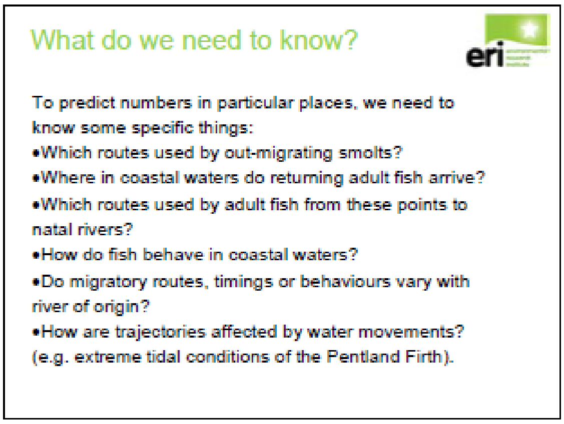












Particle models

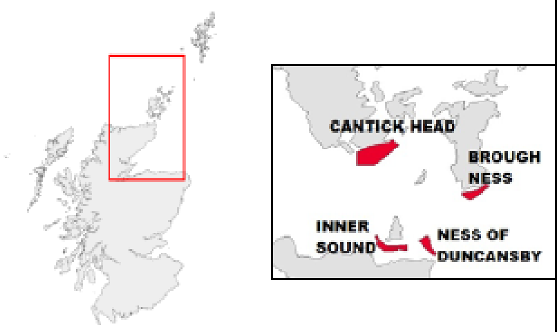
Hydrodynamic modelling to simulate water movements
- different scales
- different resolutions
- 2-D or 3-D

PTMs - tracking hypothetical 'particles' within the simulations of a hydrodynamic model.

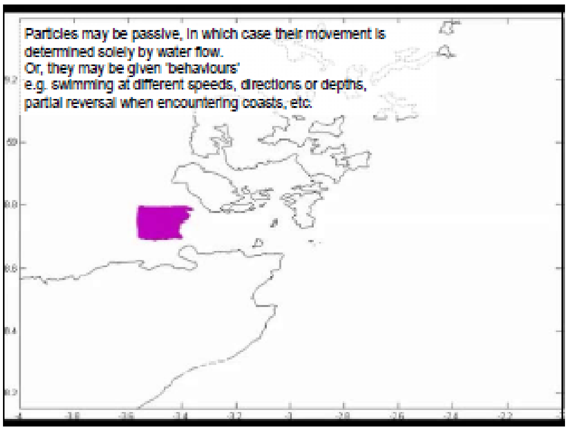
- ERI has developed a hydrodynamic model of the Pentland Firth (resolution ~200 m)
- Particle model superimposed on the output of this

Demonstration of the principle (N.B. it is not an environmental impact assessment or real data for salmon)

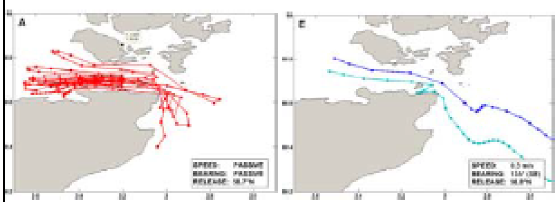
Our model



Particles may be passive, in which case their movement is determined solely by water flow.
Or, they may be given 'behaviours'
e.g. swimming at different speeds, directions or depths, partial reversal when encountering coasts, etc.



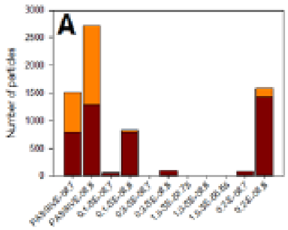
Tracking individual particles



Passive particles

0.3 ms⁻¹ to the SE

Model output



It is very clear that hydrodynamics and differences in behaviour can cause substantial differences in rates of encounters.

Is there an alternative?

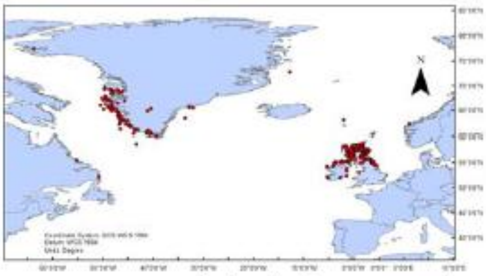
No available alternative means of estimating the risk of passage through specific proposed array locations.

A range of hydrodynamic models is available.

These models can
- allow exploration of the effects of different behaviours, tidal or meteorological conditions on encounter risk
- allow the impact of hydrodynamic changes resulting from deployment of arrays to be predicted.
- generate hypotheses for testing in the field.

Mechanisms for migration

A parsimonious conceptual model...



...for discussion, improvement, testing.

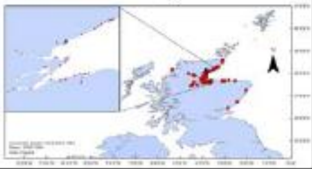
Insights to migratory routes

Historical data - reports on tagging (1901 – 1985)

- Digitised, georeferenced

Novel cellular model

- probabilistic (rather than descriptive) understanding of migration, considers the likelihood of the numbers of fish returning to particular places relative to the number which might have left.



Conclusions

Particle models are a powerful and useful tool to understand salmon migration, but only as realistic as the biological behaviours imparted.

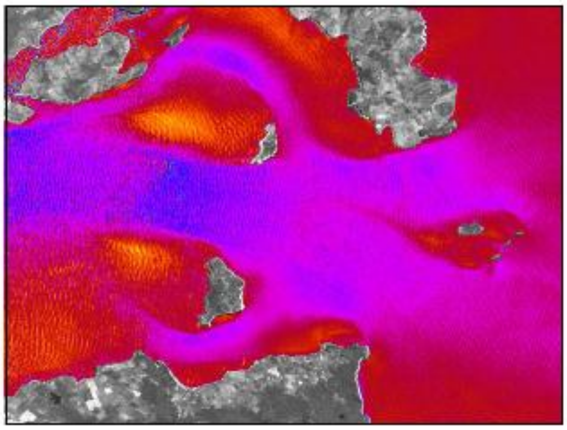
All these elements are drawn together in a Crown Estate report.

Hopefully available at the end of May.

Thanks to The Crown Estate and North Highland College UHI for supporting this work.

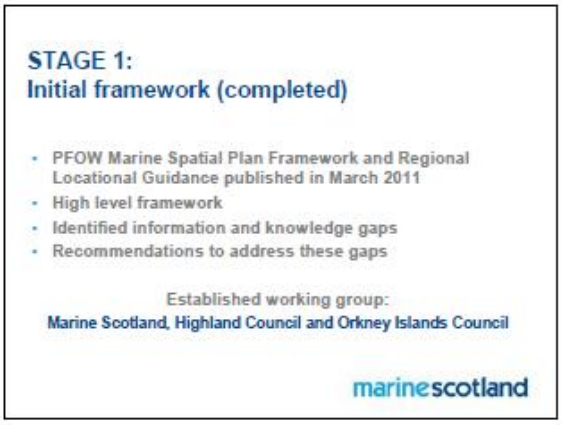
North Highland College University of the Highlands and Islands

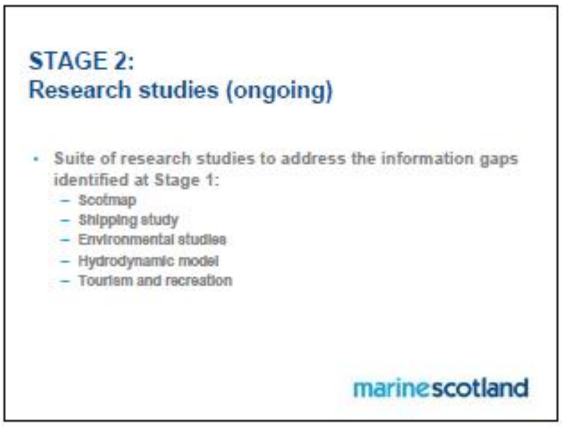
THE CROWN ESTATE

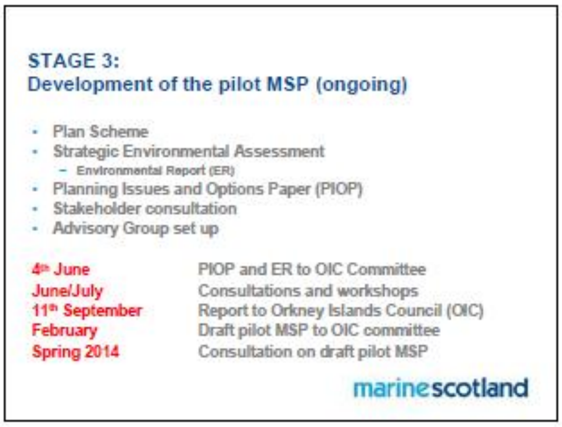


Appendix 4 Pop-up presentations

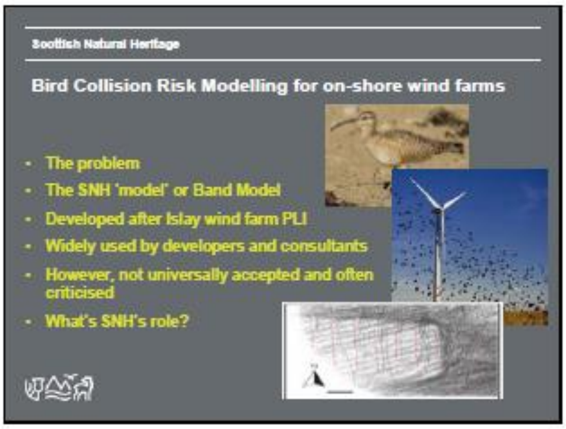
Appendix 4 a. Tracy McCollin, Marine Scotland

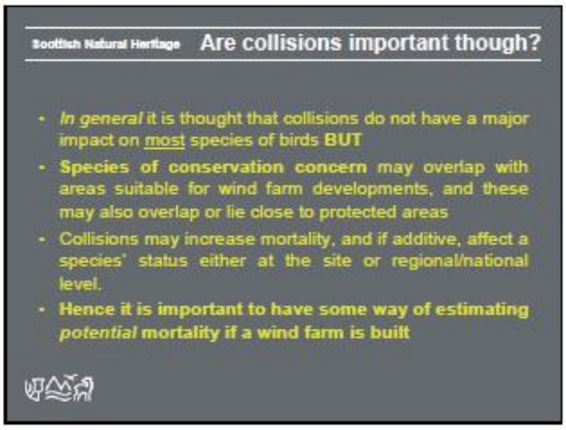


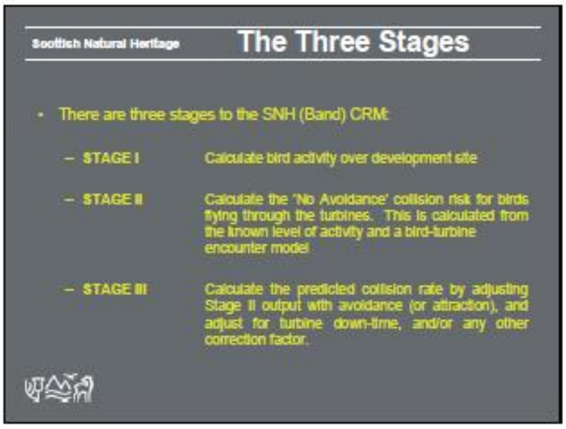


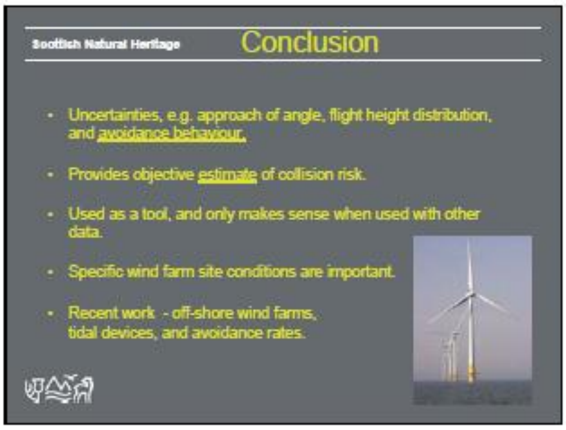


Appendix 4 b. Chris Eastham, SNH

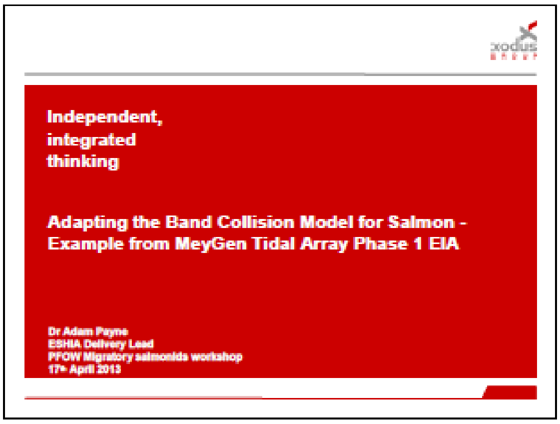


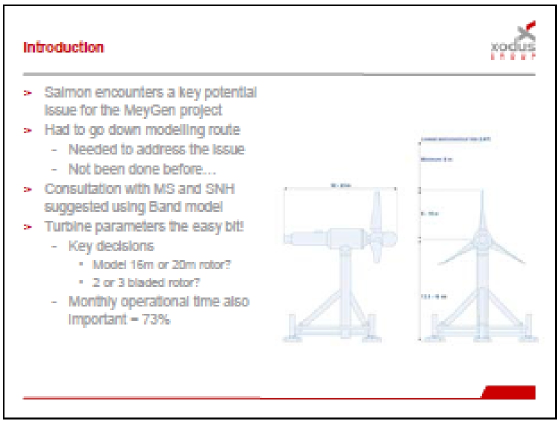


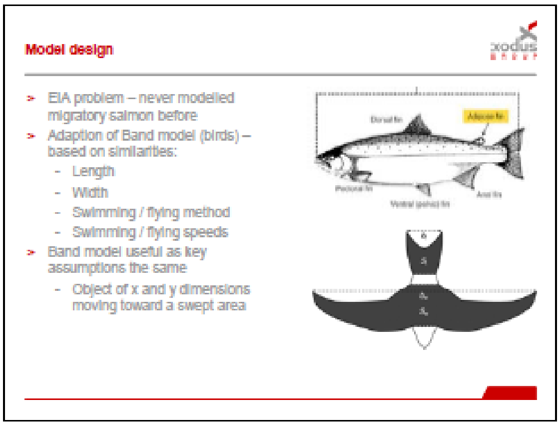


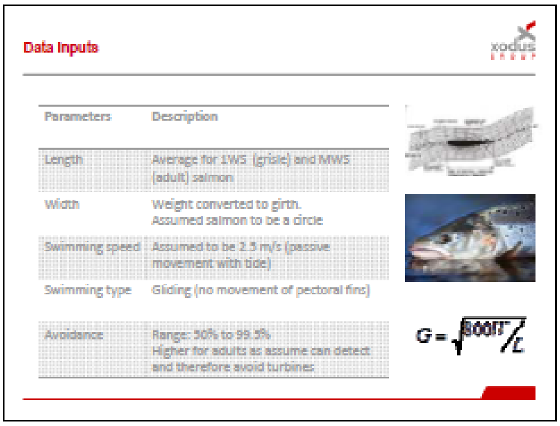


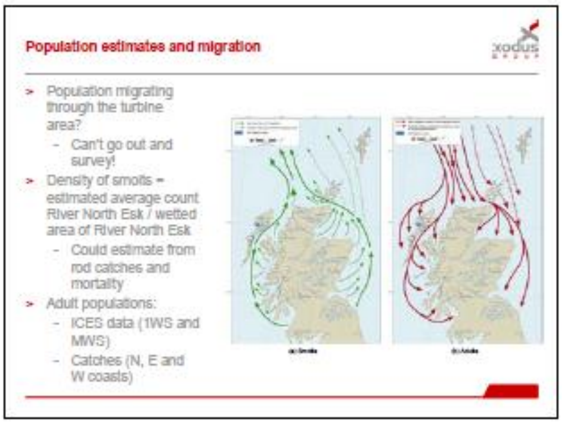
Appendix 4 c. Adam Payne, Xodus

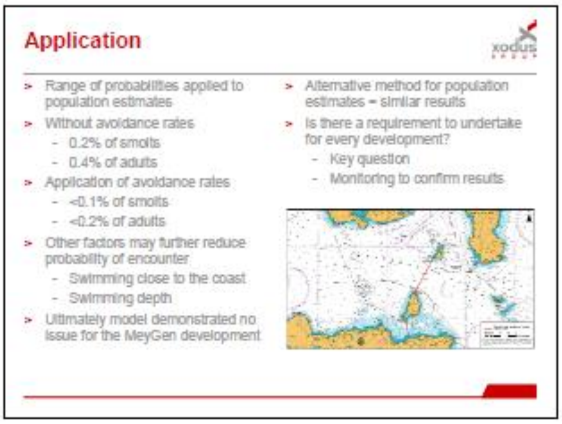




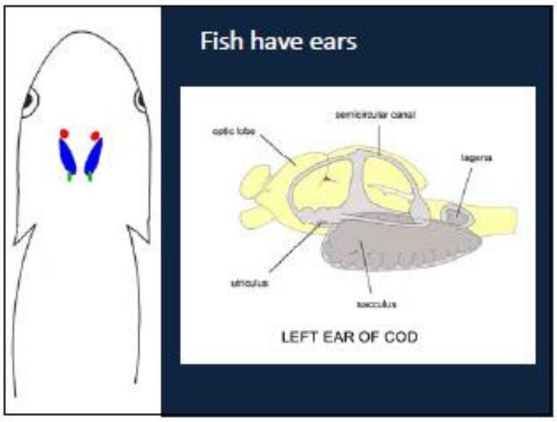


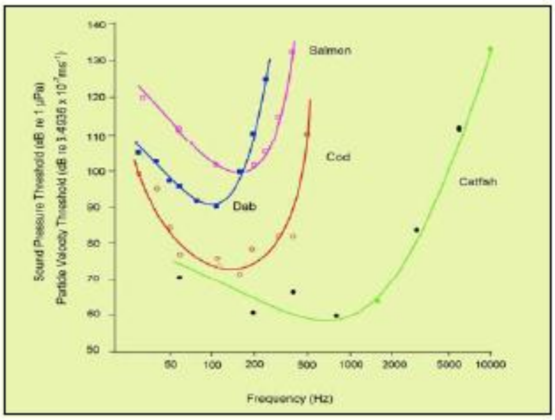


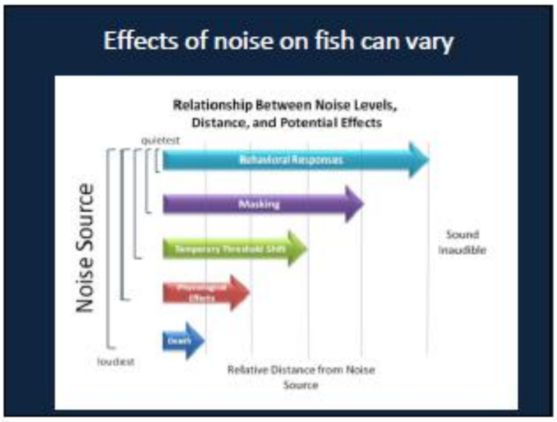




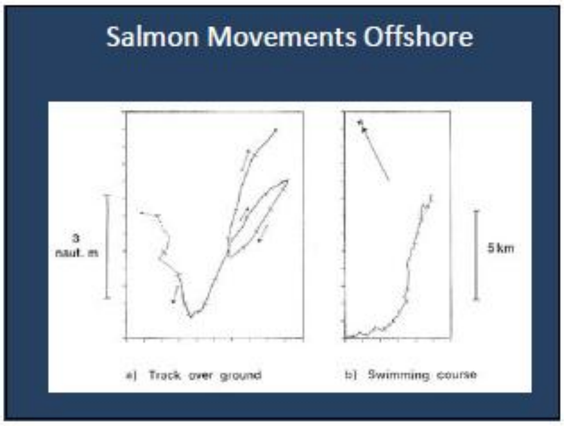
Appendix 4 d. Tony Hawkins A

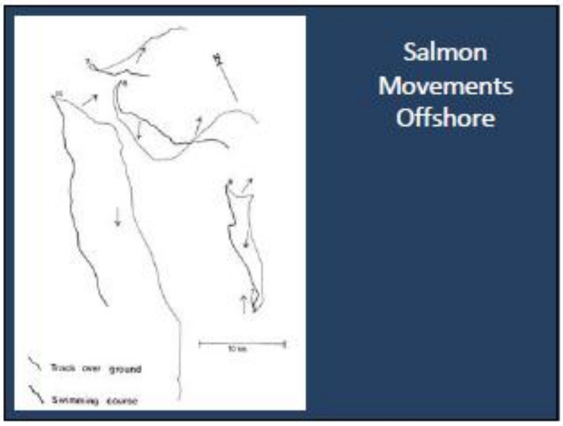


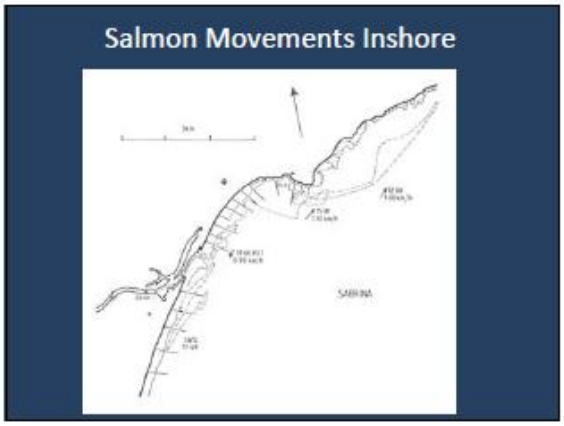




Appendix 4 e. Tony Hawkins B







Appendix 5 Review group members

Review Group Member	**Organisation**
Tony Hawkins	Workshop Chair
Toby Gethin	The Crown Estate
Mike Cowling	The Crown Estate
Richard Slaski	Epsilon Resource Management
Darren Hirst	Bidwells
Ed Rollings	MeyGen
Laura Carse	Pelamis
Douglas Watson	SPR
Ian Davies	Marine Scotland Science
Tracy McCollin	Marine Scotland – Planning and Policy
George Lees *(written submission)*	SNH
Alan Wells	ASFB

Appendix 6 Consultees to the study

Consultee	Organisation
Tony Hawkins	Workshop Chair
Mike Cowling	The Crown Estate
Toby Gethin	The Crown Estate
Ed Rollings	MeyGen
Laura Carse	Pelamis
Douglas Watson	SPR
Marten Meynell	Aquamarine
Robin Burnett	SSE
Michael Lewis	OpenHydro
David Langston	MCT
Aoife O'Keeffe	E-On
Gina Penwarden	Scotrenewables
Ian Davies	Marine Scotland Science
Tracy McCollin	Marine Scotland – Planning and Policy
Roger May	Marine Scotland Licensing Operations Team
Phil Gilmour	Marine Scotland – Planning and Policy
John Armstrong	Marine Scotland Science
Iain Malcolm	Marine Scotland Science
Angus Jackson	ERI
George Lees	SNH
Erica Knott	SNH
James Green	Orkney Islands Council
Shona Turnbull	Highland Council
Alan Wells	ASFB
Keith Williams	Ness & Beauly Fisheries Trust
James MacKay	Armadale Salmon Fishing
George Pullar	Usan Fisheries
Alan Youngson	Caithness DSFB
Crispian Cook	Northern DSFB

Shona Marshall	West Sutherland Fisheries Trust
Alastair Stephen	SSE / Institute of Fisheries Management
Chris Conroy	River Naver Superintendent

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