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Report of the Workshop on Wave and Tidal Energy Test Sites (WKWTETS)

3 May 2012

Orkney, Scotland, UK

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Executive Summary

The ICES Workshop on Wave and Tidal Energy Test Sites (WKWTETS) was held in Orkney, Scotland, on 3 May 2012, as part of the EIMR International Conference on The Environmental Interactions of Marine Renewable Energy Technologies. Presentations at the workshop described environmental, socio-economic, impact assessment and regulatory issues relevant to the development of the wave and tidal energy sector worldwide, particularly in relation to application of research at sites where marine hydrokinetic energy extraction devices are being tested. Workshop delegates completed a questionnaire addressing three Terms of Reference for the workshop: (a) collating information on wave and tidal energy test sites worldwide, identifying how these are being used to generate research findings relevant to environmental interactions applicable to full-scale commercial developments; (b) describing ongoing marine environmental research at test sites; and (c) identifying priorities for applying the findings of research and monitoring activities at test sites to full-scale commercial deployments, and identifying the research gaps that are most urgent to address at test sites.

Attendance at the WKWTETS sessions was around 100-150 delegates. Twelve presentations were made and discussed during the workshop. Completed questionnaires were returned by 43 delegates. Academic sector delegates provided 70% of the questionnaire returns. Public sector delegates, involved in planning, policy and regulation in the marine environment, were also well represented, making up 21% of returns. Returns were also provided by environmental consultants and representatives of the wave and tidal energy industry. Ecological interactions was the greatest interest area for respondents, with significant interest also in fishery interactions and marine spatial planning.

Information was provided on 31 test sites (or site groups) worldwide, ranging from high profile, large-scale sites such as EMEC (Orkney) and FORCE (Bay of Fundy) to small-scale sites being used to test specific technologies. The level of environmental and other research is very variable between sites, but overall represents a large potential resource for application to the development of the wave and tidal energy sector more generally. Research topics and baseline data collection vary widely between sites, but comprehensive programmes are present at a number of sites. This includes both biological and physical interactions as well as impacts on marine mammals, birds, fish, hydrodynamics, benthos, sediment and fisheries. In terms of both transfer of research findings from test sites to full-scale developments and research gaps that could be addressed at test sites, the highest priorities were given to the development of biological and physical monitoring protocols. Developing understanding of the various types of potential impact were also accorded high priorities by most questionnaire respondents, but lowest priority was generally given to human dimensions such as fishery value, governance and human impacts. Respondents offered a generic perspective on mechanisms for transfer of test site research findings for more general application, the most obvious mechanisms for dissemination being publicly available reports and open access publications, transfer to policy through multidisciplinary conferences and networks, and scientific cooperation.

It is hoped that the workshop findings will be useful in informing future debate on research priorities in relation to wave and tidal energy and on the application of research findings from test sites at a more general level. The unofficial subtitle for the workshop was *"wave and tidal energy test sites – what have we learned so far?"*. The main

outcome of the workshop was to demonstrate that a great deal has already been learned and that the task now is to capitalize on these findings at a worldwide level to prioritize research that still needs to be done and to apply the lessons learned so far in the development and regulation of this emerging marine industry.

1 Introduction

Reduced- and full-scale devices for extracting hydrokinetic energy from waves and tides are being tested at a number of sites worldwide. Research being undertaken alongside these test deployments is being used to provide environmental and biological baselines and monitoring methods and to determine the likely environmental and ecological consequences of commercial-scale wave and tidal energy developments. It is timely to ask: what have we learned so far? and what do we still need to learn? The ICES Workshop on Wave and Tidal Energy Test Sites (WKWTETS) was convened in Orkney in May 2012 to gather information on the nature of wave and tidal energy test sites, on how they are being used for test deployments and environmental research, and on the scope for the outcomes of this research to be applied in the environmentally sustainable development of the wave and tidal energy industry.

2 Terms of reference

2011/2/SSGHIE13 The **Workshop on Wave and Tidal Energy Test Sites** (WKWTETS), chaired by Michael Bell, UK, will meet in Orkney, Scotland, UK, 3 May 2012 to:

a) Collate information on wave and tidal energy test sites worldwide, cataloguing current and projected future device deployments and identifying site and device features that will allow research findings with respect to potential environmental impacts and interactions to be generalized across other sites and developments;

b) Describe ongoing marine environmental research being undertaken alongside device testing activities at wave and tidal energy test sites and report on scientific findings with regards to potential impacts and opportunities;

c) Provide a list of priorities for applying research findings and monitoring methods developed at test sites to full-scale commercial deployments, identifying crucial research gaps that are most urgent to address at the test sites before upscaling of commercial wave and tidal energy developments.

WKWTETS will report by 15 June 2011 (via SSGHIE) for the attention of SCICOM.

3 Workshop format

WKWTETS was timed to take advantage of two scientific events in Orkney relating to wave and tidal energy. The 2012 meeting of the ICES Study Group on Environmental Impacts of Wave and Tidal Energy (SGWTE) followed WKWTETS in Stromness on 4-6 May 2012, whilst the EIMR International Conference 2012 (Environmental Interactions of Marine Renewable Energy Technologies, www.eimr.org) was held on 30 April – 4 May 2012 in Kirkwall. These two events meant that there was a large number of scientists and stakeholders with interests in marine renewable energy and the environment present in Orkney, interested and available to participate in WKWTETS. In particular, with more than 200 delegates to EIMR, this presented an opportunity for a level of international participation in the workshop that would otherwise be unlikely in such a remote location. Accordingly, it was decided to incorporate WKWTETS within the overall conference programme (see Appendix II).

Given potential participation of up to 200 delegates in the workshop, it was decided that a round table discussion format was not appropriate. Instead, the workshop programme took the form of a series of presentations with opportunities for discussion, with Terms of Reference for the workshop more specifically addressed through a questionnaire distributed to all delegates (Appendix IV). Abstracts of presentations are given in Section 4 of this report and rapporteur notes of the presentation session are attached at Appendix III. A summary and analysis of questionnaire results is given in Section 5. During the WKWTETS conference sessions on 3 May the attendance was in the region of 100-150 delegates. Appendix I lists the participants who made presentations, returned questionnaires or otherwise made individually identifiable contributions to the workshop.

4 Abstracts of workshop presentations

Tidal Power from the Bay of Fundy, Canada: Environmental & Socio-economic Considerations. Daborn, G.R. and Redden, A.M.

Over the last 100 hundred years, the potential of the tidal movements in the Bay of Fundy (Nova Scotia, Canada) for electricity production has been assessed more than a dozen times. These schemes have included both potential energy (e.g. barrage-based) approaches and kinetic energy (TISEC) devices, and generated extensive research into the Bay of Fundy ecosystem. Studies have assessed the implications of both turbines and barrages on fish, mammals and birds, on hydrodynamics (e.g. current flows, mixing parameters, tidal range, phase etc.), sediment dynamics, groundwater movements and primary and secondary production processes. Because impedance of flow associated with tidal barrages has the potential for effects over great distances, and because the annual migrations of numerous species of fish, birds and mammals link the Bay to North, Central and South America and both the North and South Atlantic, the scope of environmental studies has been geographically wide. A 20MW tidal generating station established at Annapolis Royal in 1985, has served as a platform for research into nearfield environmental effects, particularly the direct effects of turbine passage on fish and mammals, and the local effects on groundwater, sediments and biota.

In 2008, Nova Scotia began to explore the potential of commercial-scale TISEC devices in the Bay of Fundy. A Strategic Environmental Assessment involved extensive community input, and recommended a phased approach that would examine the potential and implications of both large-scale arrays and small-scale local installations. A major testing facility in Minas Passage is being developed as the Fundy Ocean Research Centre for Energy (FORCE), with four cabled berths. Tests of smaller scale devices are being conducted in other high flow passages. FORCE has recruited an independent advisory group (EMAC) of scientists from academia, government, and local resource users, to advise on design of the monitoring programme and interpretation of results. In addition, an independent group of natural and social scientists formed the Fundy Energy Research Network (FERN), which is hosted by Acadia University. Research initiatives include: hydrodynamic and sediment modelling; monitoring movements of fish and marine mammals; implications for shoreline erosion, ice formation and mobilization, and submerged debris; effects on benthos and plankton; primary and secondary production; and on socio-economic implications (e.g. fisheries displacement, community development, supply chain implications, etc.).

This presentation will review both the scope of the monitoring and assessment programme, and the challenges presented – especially the technical challenges of monitoring in high flow environments.

Monitoring marine mammals at the world's first operational commercial scale tidal energy device – 3 years post-installation. Sparling, C.E., Hastie, G.D., Duck, C., McConnell, B.M., Lonergan, M.E., Mackay, A.I., Booth, C.G., Northridge, S., Savidge, G., Birkett, D., McKenzie, M., Donovan, C., Ainsworth, D. and Boyd, I.L.

MCT's SeaGen turbine has been operational in Strangford Lough since July 2008. Strangford Lough is an environmentally sensitive area and has several conservation designations. One of the qualifying features is a breeding population of harbour seals. Grey seals and harbour porpoise are also frequently seen there. A monitoring programme has been in place since 2006, examining the effects of the turbine across different spatial and temporal scales. Three years post-installation, we've detected no significant effects of the turbine, although some local displacement of porpoises and seals may have occurred. The challenge is to use these results to scale up from single devices to arrays and to develop cost-effective monitoring methodologies at future developments.

Monitoring Orkney's High-Energy Littoral Environment: Photographic and Image Analysis Methodologies for Quantifying Species and Biotope Coverage. Want, A., Side, J.C. and Bell, M.C.

The West Mainland shoreline of Orkney is characterized by dramatic sandstone cliffs, complex geomorphologic features including sea stacks and caves, and a few embayments. With a westerly fetch of over 3000 km, wave energy plays a dominant role in both shaping this landscape and determining the ecological community. Access to this considerable wave energy resource has been one of the factors in the recent decision to deploy energy extraction devices off this coastline. We have begun a long term monitoring programme to assess the consequences of altering wave energy exposure on these rocky shores alongside responses to other systemic forcing agents such as climate change. Within this programme are several photographic surveys including quadrat and fixed view point techniques used to study individual species and biotopes. In addition, we have developed software for economically analysing these images and producing quantitative baseline data on species and biotope coverage.

Assessing effects of tidal hydrokinetic devices on fishes at deployment and ecosystem scales. Zydlewski, G., McCleave, J., Staines, G., Viehman, H. and Vieser, J.

Fish are a key part of the Cobscook Bay ecosystem likely to be affected by marine hydrokinetic devices in Eastport, Maine, USA. Our research on these effects consists of three approaches: 1) Active acoustics documenting vertical fish distribution at proposed deployment and control locations through tidal, diel, and seasonal cycles. 2) DIDSON acoustic imaging fore and aft of a device to document behavioral responses through complete diel and tidal cycles. 3) Seine, fyke, and trawl sampling to document fish community structure. The strength of our approach is pre- and post-deployment data and both experimental and control sites for quantitative comparison.

Short-term Temporal Behavioural Responses in Pollack, Pollachius pollachius to Marine Tidal Turbine Devices; a Combined Video and ADCP Doppler Approach. Broadhurst, M. & Barr, S.

Combining biological and environmental survey techniques can further knowledge relating to species behavioural responses to marine energy technologies. Underwater video footage was integrated with ADCP doppler surveys to assess behavioural responses of Pollack, *Pollachius pollachius* to a deployed OpenHydro turbine at EMEC.

Surveys were conducted within 16 day trial periods during summer of 2009 and 2010 with fish abundance being compared to hour and day temporal scales and ADCP tidal velocity flow rates between years. Overall the study outlined a different approach to investigate behavioural responses with new anthropogenic activities.

Environmental monitoring at EMEC. Norris, J.

EMEC undertakes baseline monitoring of the receiving environment at all its four test sites. Data collected is driven by regulatory need (typically expressed as conditions on developers' licences to deploy their marine energy devices). Monitoring includes wildlife presence and behaviour, and acoustic characterization of the sites. There are some data collection recommendations for which there are as yet no 'best practice' methodologies, and for which therefore such methodologies need to be developed and tested. The paper will describe EMEC's involvement in a range of environmental and other research projects, which include wildlife distribution, acoustic characterization of the deployment sites, and a ground-breaking fisheries project that works collaboratively with local fishers and looks at the distribution of lobster around the EMEC wave site.

Getting Devices in the Water - Understanding Environmental Effects of Marine Energy Development in the USA. Copping, A.

The US is deploying initial tidal and wave energy conversion devices, with leadership from the US Department of Energy. The permitting (consenting) process is complex, lead by numerous agencies, and requires a very high level of understanding of potential environmental effects. Pacific Northwest National Laboratory, in partnership with other national laboratories, university partners and the industry, pursues research that addresses permitting needs and fills gaps in understanding effects. Results of studies will be presented on effects of electromagnetic fields, acoustics, direct interactions with marine animals, and risk assessment processes. A knowledge management system that organizes and presents effects will be demonstrated.

Gathering the perspectives and experience from test sites and device developers for Environmental and Socio-economic Impact Assessment of Wave Energy. Magagna, D., Greaves, D.M., Conley, D., O'Hagan, A.M., Holmes, B., Witt, M., Simas, T., Huertas Olivares, C., Chambel Leitão, J., Mouslim, H., Torre-Inciso, Y., Sundberg, J. and Rousseau, N.

The SOWFIA (Streamlining of Ocean Wave Farms Impact Assessment) project aims to make recommendations to streamline impact assessment and to develop coordinated tools that will contribute to advancing the wave energy sector across Europe. This paper examines the types of, and methods used in, environmental scoping studies whilst investigating the applicable consenting process in six test sites in different jurisdictions. The experiences of site and device developers in relation to consenting and financing of scoping studies were gathered in order to understand the non-technological barriers that the wave energy industry faces. The capturing of such experience highlights the urgent need to adopt a common approach to Impact Assessment and thereby facilitate development of the sector.

5 Questionnaire results

The Terms of Reference for WKWTETS were addressed by using a questionnaire distributed to workshop delegates (see Appendix IV). A total of 43 questionnaires was returned and the following sections are an account of the responses in relation to each ToR.

5.1 Profile of questionnaire respondents

The academic sector was strongly represented in the survey, comprising 70% (30 out of 43) of all respondents (Figure 5.1). Academic roles ranged from PhD student to senior lecturing and research posts. Public sector delegates were also well represented, making up 21% (9 out of 43) of respondents. This group included individuals involved in planning, policy and regulation in relation to the marine environment. The remaining 9% (4 out of 43) were split equally between environmental consultants and representatives of the wave and tidal energy (WTE) industry. Twenty-six respondents (60%) were involved in research or monitoring activities at WTE test sites, and 16 of these (37% of all respondents) were also directly involved in WTE testing activities, these proportions being roughly similar between the academic and public sector groups.

Respondents were asked to register their areas of interest in relation to wave and tidal energy (Figure 5.2). The most popular topic by far was *ecological interactions*, with 84% of respondents expressing an interest. *Fishery interactions* and *marine spatial planning* were also of interest to more than half of respondents. Some differences were apparent between the academic and public sector groups, with the latter much more likely to be interested in *marine spatial planning*, *consenting and regulation*, *fishery interactions*, *impacts on physical processes* and *device development and testing*. In addition to the options listed on the questionnaire, individual respondents also expressed interests in biofouling, local knowledge, cumulative effects (two respondents), co-location of activities, environmental due diligence and risk assessment.

5.2 ToR a) Collate information on wave and tidal energy test sites worldwide, cataloguing current and projected future device deployments and identifying site and device features that will allow research findings with respect to potential environmental impacts and interactions to be generalized across other sites and developments

Respondents were asked to provide information on WTE test sites that they were aware of, giving information on deployments and the general applicability of research outcomes. A total of 119 responses was returned by 35 respondents, providing information on 31 test sites or site groups (Table 5.1). Almost three quarters of respondents demonstrated at least awareness of the European Marine Energy Centre (EMEC), but mostly did not distinguish between the separate wave and tidal test sites around Orkney, nor between the full-scale and nursery sites. Awareness of the Wave Hub test site off southwest England was also high, and outside the UK the highest profiles were for the Bay of Fundy tidal test sites in Canada and the Oregon wave test sites in the USA. Sites at twelve countries were represented in the questionnaire, namely UK, USA, Canada, Ireland, Spain, Portugal, France, Sweden, New Zealand, Australia, Denmark, Japan, listed in order of decreasing number of responses.

It is unlikely that the data are comprehensive or fully accurate, but Table 5.1 gives a good overall summary of the distribution of WTE test sites around the world, how they are being used and the general applicability of the research. Overall, it can be seen that WTE site sites worldwide, together with the device testing and research activities they support, represent a huge potential resource for application to the development of the WTE sector more generally. Some research is site-specific, such as baseline studies and resource assessment, or technology-specific, such as device performance testing, but even in these cases there may be wider benefits in terms of developing monitoring technologies and protocols. Public funded research at major national test facilities, such as EMEC in the UK and the Northwest National Marine Renewable Energy Center (NNMREC) at Oregon in the USA, probably provides the best resource of generally available information, particularly on environmental interactions and impacts. Owing to commercial sensitivity, access to industry-funded research outcomes is more problematic, but it is likely that there exists a large resource of generally applicable information from such research.

5.3 ToR b) Describe ongoing marine environmental research being undertaken alongside device testing activities at wave and tidal energy test sites and report on scientific findings with regards to potential impacts and opportunities

The questionnaire asked for information on marine environmental research being undertaken at WTE test sites, making a distinction between baseline data collection and research relevant to environmental impacts and opportunities from WTE developments. Twenty-seven respondents provided information, mostly on generic research activities at test sites rather than specific research programmes, and this has allowed a research profile for each test site to be drawn up.

Table 5.2 lists numbers of responses indicating each type of baseline data collection activity at WTE test sites. The number of responses is likely to reflect both the existence of an activity type at a given site and the awareness of that activity within the group of respondents. Respondents reported awareness of baseline data collection at eleven sites or groups of sites. The European Marine Energy Centre (EMEC) had the highest profile for baseline data collection, but most respondents did not distinguish between the different EMEC sites: Billia Croo and Falls of Warness, the grid-connected full-scale test sites for wave and tidal energy devices respectively, and Scapa Flow and Shapinsay Sound, the nursery test sites for wave and tidal energy devices respectively. Similarly, many respondents were aware of research at tidal energy test sites in the Bay of Fundy, but did not distinguish between the Fundy Ocean Research Centre for Energy (FORCE) and Fundy Tidal Inc. EMEC, Wave Hub and Bay of Fundy sites were all well represented in the responses, each showing a good range of activities relating to most types of baseline data collection. Baseline data collection appears comprehensive also for Ramsey Sound and Strangford Lough sites. In some cases, such as Ramsey Sound, this relates mainly to plans for future data collection rather than data that have already been collected. Baseline data on the physical environment and on mammals, fish and birds appear to be most widely collected. Data on human use of sea areas are lacking for several sites.

Much research relevant to impacts and opportunities arising from WTE developments is being undertaken at WTE test sites, as shown by responses giving information on eleven sites or groups of sites (Table 5.3). As with the baseline data collection, the highest research profile is shown for the EMEC sites, followed by Wave Hub and Bay of Fundy. Wave Hub is the only site for which responses were recorded across all research areas, but comprehensive research programmes covering both biological and physical interactions were identified at all three of these sites, as well as at Ramsey Sound, Lysekil, Admiralty Inlet, the Biscay Marine Energy Platform (BIMEP) and Oregon sites. Research into the potential for WTE development activities to impact upon marine mammals had the highest profile among the respondents, followed by impacts on birds, fish, hydrodynamics, benthos, sediment and fisheries. Research into potential impacts on fish appears to be most widespread, with responses indicating activities at all eleven sites. Research relevant to fishery management and fishery stock enhancement had the lowest profile in terms of number of responses. In addition to the research areas highlighted in the questionnaire, respondents also identified test site research into biodiversity impacts from biofouling (EMEC), underwater noise (Lysekil, EMEC), ecosystem effects (EMEC) and shipping (Bay of Fundy).

5.4 ToR c) Provide a list of priorities for applying research findings and monitoring methods developed at test sites to full-scale commercial deployments, identifying crucial research gaps that are most urgent to address at the test sites before upscaling of commercial wave and tidal energy developments

The questionnaire sought respondents' views on priorities for transferring findings of environmental and ecological research at test sites to full-scale developments, and asked for comments on how findings should be transferred. Thirty-seven respondents provided responses on at least one of the research topics, scoring priorities on a scale of 1 (low priority) to 5 (high priority). Average priority scores for each topic were calculated on the assumption that absence of a score for a particular topic represented no view on the priority for that topic rather than a lack of priority (Figure 5.3). In case the results are sensitive to this assumption, a second data summary was prepared in which the number of mid to high priority scores (3-5) assigned to a topic area was expressed as a percentage of the number of respondents, irrespective of whether all respondents had assigned a score for that topic (Figure 5.4).

Both analyses demonstrate a remarkably even spread of priorities across the different topic areas, but consistently showed *biological monitoring protocols* as being the number one priority for transfer of findings from test sites to full-scale WTE developments. *Physical monitoring protocols* and various types of impact were also identified as high priorities for transfer of findings. Consistently across sectors and measures of priority, research into the human dimension was considered least applicable for transfer from test sites; this included *human impacts*, *governance*, *fishery value* and *socio-economics*. This perhaps reflects less on the overall importance of general research on these topics than on the suitability of WTE test sites as test beds for these types of research.

Under the same ToR, the questionnaire asked for respondents' views on crucial research gaps that should be addressed at test sites, again prioritized on a scale of 1 to 5. The responses have been analysed in the same way as for priorities for research transfer. The results are broadly consistent between the two analyses (Figures 5.5 and 5.6) and between the analyses of research transfer priorities and research gaps (c.f. Figures 5.3 and 5.4), and it seems likely that the responses reflect perceptions of the general importance of each research topic as much as of the utility of test sites for providing research outcomes that can be applied more widely. *Monitoring protocols*, both *biological* and *physical*, were identified as high priorities for use of test sites to address research gaps, particularly by the public sector respondents, and lowest priority was again given to the human dimension, particularly *human impacts*, *governance* and *fishery value*. Among the impacts, those on *fish* were identified as the highest priority research gap, higher than *mammal* and *bird impacts*, indicative of the relatively low emphasis that has hitherto been placed on this research topic compared with the higher vertebrates.

Given the similarity of responses between transfer priorities and research gaps, outcomes are summarized jointly below, given in descending order of average priority (figures in parenthesess are numbers of responses):

- *Biological monitoring protocols*. Average priority scores: research transfer 4.5 (32); research gaps 4.5 (27). These protocols refer to monitoring all aspects of the biota occurring in and around potential WTE development areas, from benthos to birds and mammals, providing information on abundance and spatio-temporal patterns of site use. As highlighted by one respondent, it is important that monitoring should encompass spatial and temporal variability rather than simply providing a snapshot of biological conditions at a site. Monitoring protocols are relevant both to establishing baseline conditions and to measuring responses to development. There was a very high level of response on this topic, with scores for both transfer priorities and research gaps mostly in the range 4 to 5. Comments on this topic indicated that research at test sites would be valuable for developing standards for monitoring methods that could be agreed for application to full-scale developments at national and international levels. Several UK respondents highlighted the need for coordinated UK guidance on both biological and physical monitoring protocols, agreed between the national agencies; it was suggested that the Offshore Renewable Energy Licensing Group (ORELG) could be a vehicle for such guidance and attention was drawn to a list of issues that require resolution in order to facilitate the licensing of offshore renewables projects[1]. One respondent suggested that standardized monitoring protocols should be extended to invasive non-native species, with clear procedures for recording and notification of statutory authorities.
- *Physical monitoring protocols*. Average priority scores: research transfer 4.3 (29); research gaps 4.1 (24). Physical monitoring is likely to centre on hydrodynamics and sediments, and as with biological monitoring is applicable to both baseline and impact measurements. Baseline hydrodynamic measurements might be included as part of energy resource assessment by WTE developers and planners, and hydrodynamic changes resulting from the presence of devices and extraction of energy are relevant both to energy planning and environmental protection. Similarly, sediment studies are relevant to WTE development activities at the most practical level, as well as to measuring environmental impacts. Most respondents considered it high priority (scores 4-5) for outcomes of research into physical monitoring methods to be transferred from test sites to full-scale developments. Similar to biological monitoring, respondents indicated the need for standards developed at test sites to be taken forward into coordinated national and international guidance.
- *Fish impacts*. Average priority scores: research transfer 4.2 (28); research gaps 4.1 (26). Given the likely strong overlap between WTE development

[1] http://marinemanagement.org.uk/licensing/groups/documents/orelg/issues_list.pdf

activities and fish habitat, it is perhaps not surprising that respondents should identify research into potential impacts on fish as a relatively high priority for transfer from test sites to full-scale developments. There is a general perception that fish impacts have received less attention than impacts on organisms that are more visible and for which there is a higher level of public awareness, such as marine birds and mammals. Possibly this indicates that although baseline data collection on fish and research into impacts is widespread at test sites (Tables 5.2 and 5.3) the intensity of this research is lower than for some other groups, and there remains scope for increased effort in this area. Most respondents who expressed a view considered this as a mid to high level priority for transfer of findings from test sites. Research gaps identified by respondents included understanding the use of the environment by fish, behavioural interactions with WTE devices, how collision risk is related to avoidance and evasion behaviour, technology for long term monitoring of impacts, understanding fish population structure and connectivity. With the possible exception of the last topic, studies addressing these gaps are all suitable to be undertaken at test sites, with lessons for design and placement of full-scale WTE developments and ongoing monitoring activities at these sites.

- *Mammal impacts*. Average priority scores: research transfer 4.1 (29); research gaps 3.9 (24). As noted by one respondent, potential impacts on mammals is a key issue which causes problems in the consenting process, the immediate issue being collision risk. The respondent also noted that as arrays get larger and more widespread disturbance and displacement are likely to become more of an issue. Most respondents agreed that transfer of findings from test sites to full-scale developments is a high priority for marine mammal impacts, although one noted that research findings are unlikely to be robust at sites that have already been impacted. Similar to fish impacts, understanding of collision risks in relation to evasion and avoidance behaviour, and technology for long-term monitoring were identified as important research gaps, and WTE test sites are likely to be important foci for such research. One respondent noted that the highest priority should be given to research on collision risk because of statutory protection of marine mammal species and the obligations on regulators to understand and quantify risks.
- *Hydrodynamic impacts*. Average priority scores: research transfer 4.0 (31); research gaps 3.9 (27). Hydrodynamic impacts are likely to stem both from the physical presence of devices and from the extraction of energy. Impacts might take the form of changes in wave climate and circulation patterns, potentially extending to far-field scales (10s of kilometres and further). Understandably, most studies have so far been based on hydrodynamic models, but there may be scope for research at WTE test sites to play a role in validating and parameterizing models and for physical measurements particularly in the nearfield. Respondents highlighted the need to transfer results across scales, and to incorporate increasing degrees of complexity of device structure in hydrodynamic studies. Understanding potential changes in wave and current regimes resulting from energy extraction was identified as an important research gap, and one reviewer noted the need for experimental studies of changes in tidal flood velocity.

- *Benthic impacts*. Average priority scores: research transfer 4.0 (31); research gaps 3.8 (22). Benthic impacts refer to damage and changes in benthic communities in response to development activities. This might include ecosystem effects and far-field effects of energy extraction as well as direct impacts from WTE operations (construction, maintenance, operation, decommissioning) on benthos in the immediate vicinity of developments, but the latter (nearfield) is perhaps most relevant to WTE test sites, and one respondent noted that there is a large potential for research findings to be transferred across scales. Of those expressing a view, most respondents accorded benthic impacts mid to high level priority in terms of both research gaps and transfer of research findings to full-scale developments. One respondent commented that at the demonstration scale benthic impacts can easily be avoided by micro-siting of devices, but noted that in practice this may be unlikely to be an issue for consenting. Another respondent pointed out that very little is known about potential responses at the organism scale.
- *Sediment impacts*. Average priority scores: research transfer 4.0 (29); research gaps 3.8 (24). As with (and related to) benthic impacts, sediment impacts may include both near and far-field effects, the former principally in terms of scour and deposition around device structures, the latter in terms of changed regimes of sediment transport and erosion. The nearfield effects are probably of greatest relevance to research at WTE test sites. Most respondents who expressed a view scored transfer and research gap priorities at the mid to high level, one commenting that the secondary consequences for ecosystems are an important area for future research. One respondent considered that sediment impacts are more of an issue for array scale than demonstration projects, but another highlighted the need for examining erosion at WTE test sites in an experimental context.
- *Noise levels*. Average priority scores: research transfer 4.0 (31); research gaps 3.7 (30). Noise emissions from construction and device operation are often considered as a form of marine pollution. There was a divergence of opinion on transfer and research gap priorities, with a number of academic respondents scoring this issue at the low end of the scale. Public sector respondents were much more likely to score noise impacts as high priority, reflecting the likely importance of noise as an issue for regulators, particularly in relation to effects on marine mammals. As with other impact types, some respondents highlighted the technologies for long-term monitoring as a need that could be addressed by research at test sites. Other research gaps noted included understanding sound output in the near and far fields under varied weather conditions. Similar to benthic impacts, one respondent noted that noise research has large potential to be transferred across scales, hence test sites are identified as being a valuable resource for such research.
- *Bird impacts*. Average priority scores: research transfer 3.7 (28); research gaps 3.5 (24). Impacts on birds might include direct effects, e.g. through collision, as well as wider ecological effects acting through changed ecosystem and physical processes. As with other types of impact, direct and smaller scale effects are most suitable to be studied at WTE test sites. Respondents had mixed views on the priorities for transfers and research gaps, one noting that a great deal of research on bird impacts has already

been undertaken and that the potential for impacts may have been overrated. It is, however, undoubtedly the case that potential bird impacts are a major issue for regulators and for the consenting process generally. One respondent further commented that bird impacts may become more of an issue as the WTE sector scales up. Protocols and technology for long-term monitoring are an important topic for research at test sites that could be transferred to full-scale developments.

- *Socio-economic impacts*. Average priority scores: research transfer 3.5 (27); research gaps 3.7 (22). Socio-economic impacts of WTE energy are likely to relate to employment, infrastructure and supply chains in areas local to development, as well as to interactions with other sea users (fisheries, aquaculture, shipping, port users), and may be both positive and negative. Enthusiasm for socio-economic research was not widespread among the respondents, but several accorded this area a high priority for WTE test sites in terms of both transfer of research findings and addressing research gaps. One respondent highlighted mechanisms for including stakeholders in decision-making as an important research topic, another emphasized the necessity for training of local people; both these topics are capable of being addressed at test sites with findings transferred more widely. A respondent noted that that research into socio-economics and governance will be increasingly important moving towards commercialization.
- *Fishery value*. Average priority scores: research transfer 3.3 (25); research gaps 3.6 (20). Fisheries were included in the questionnaire as the sea use most likely to interact with WTE developments. Similar to socio-economic impacts, not all respondents considered this a high priority area for research at test sites, but several high scores were nevertheless assigned. Fishery value has both biological and socio-economic dimensions: one respondent highlighted the importance of research into protection of spawning potential in target stocks, whilst another emphasized the effects on local economies.
- *Governance*. Average priority scores: research transfer 3.4 (24); research gaps 3.4 (17). Governance relates to policy, regulation, consenting, management and guidelines. Questionnaire respondents accorded this a relatively low priority for research at WTE test sites.
- *Human impacts*. Average priority scores: research transfer 3.0 (27); research gaps 3.4 (20). Respondents rated human impacts as the lowest priority area for research at WTE test sites. In part, this may be due to a lack of clarity over what this type of impact actually means, but a scatter of high priority scores from both academic and public sector respondents suggests that there may be some potential for research in this area, e.g. into interactions of WTE developments with recreational activities.

Several additional research areas for WTE test sites were identified by respondents, namely biofouling (e.g. methods for effective resistance), landscape/seascape (e.g. guidelines on marker and lighting requirements) and decommissioning for transfer of findings to full-scale developments, and engineering issues (e.g. rapid shut-down procedures), electromagnetic fields (a significant lack of basic understanding), scientific community (the need to work together through Europe) and cumulative impacts (e.g. in relation to 'Rochdale envelope guidance'[2]) in relation to research gaps.

Respondents were asked to comment on how research findings should be transferred from test sites for application in the development of WTE more generally. Responses were at a generic level, highlighting several obvious mechanisms for dissemination:

- transfer of findings through publicly available publications and reports, with an emphasis on open access journals since engineers, developers and others outside academia do not necessarily have access to most scientific journals;
- transfer of findings to policy, communicated through multidisciplinary conferences, workshops, meetings and networks;
- transfer of findings through scientific cooperation.

[2] http://infrastructure.independent.gov.uk/wp-content/uploads/2011/02/Advice-note-9.-Rochdale-envelope-web.pdf

6 Acknowledgements

The Chair of WKWTETS would like to thank Jim Brown, organizer of the EIMR International Conference, for incorporating WKWTETS in the conference programme and for being hugely supportive in organization and aligning conference presentations with Workshop objectives. Thanks also to the staff of the Pickaquoy Centre in Kirkwall for providing excellent conference facilities. Finally, thanks to all who participated in WKWTETS and provided much useful information in questionnaire responses, and to Vivian Piil and other staff at ICES for facilitating the production of this report.

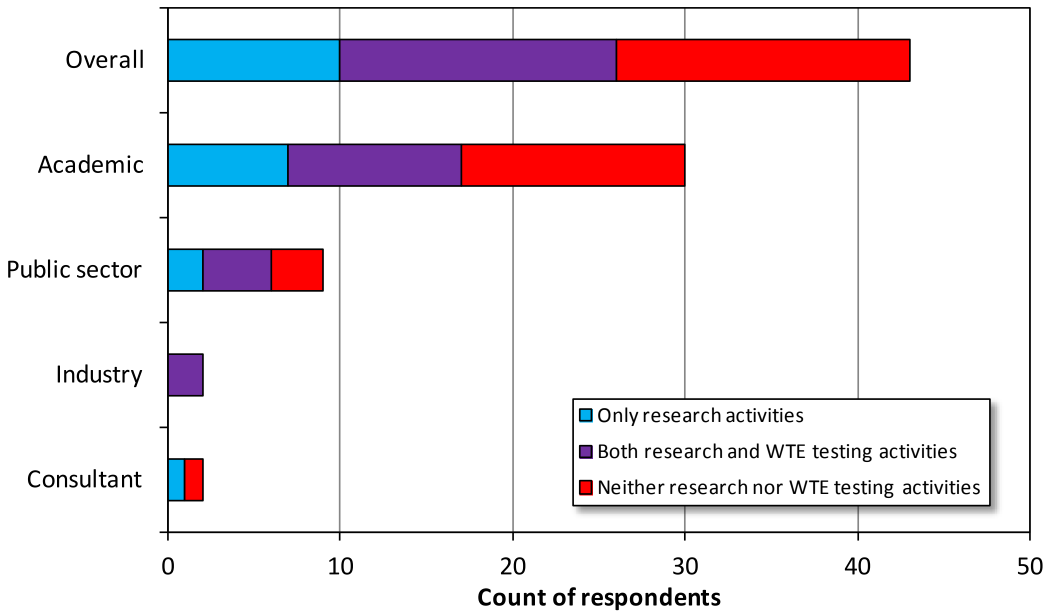

Figure 5.1. Involvement of questionnaire respondents in research and monitoring at wave and tidal energy (WTE) test sites and WTE testing activities.

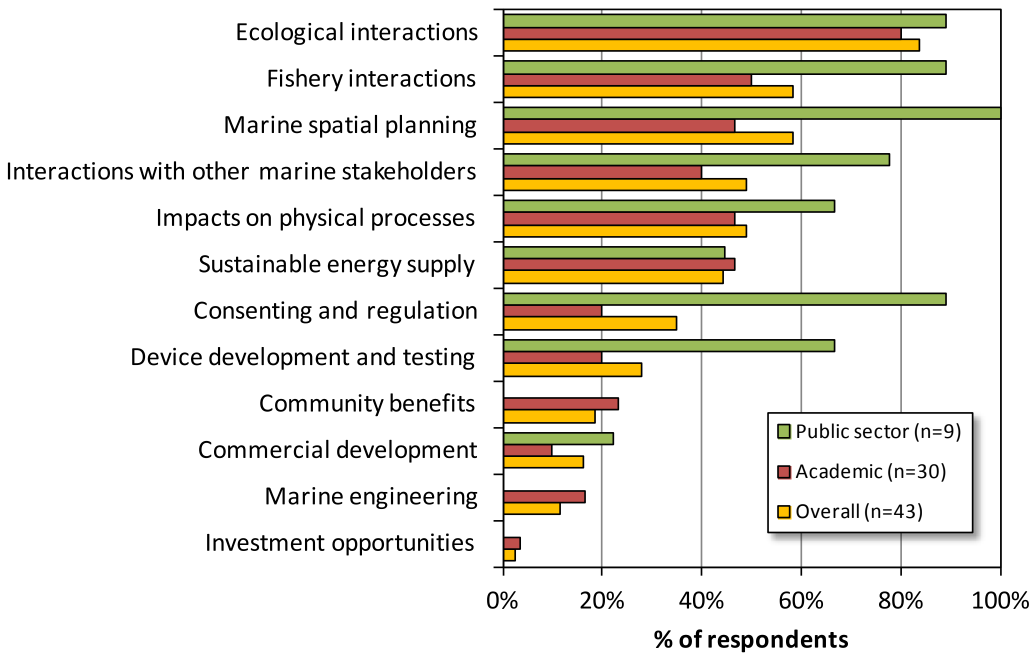

Figure 5.2. Profile of interest areas for questionnaire respondents. Profiles for public sector and academic respondents are shown separately. The overall figures include two marine renewable energy industry representatives and two environmental consultants.

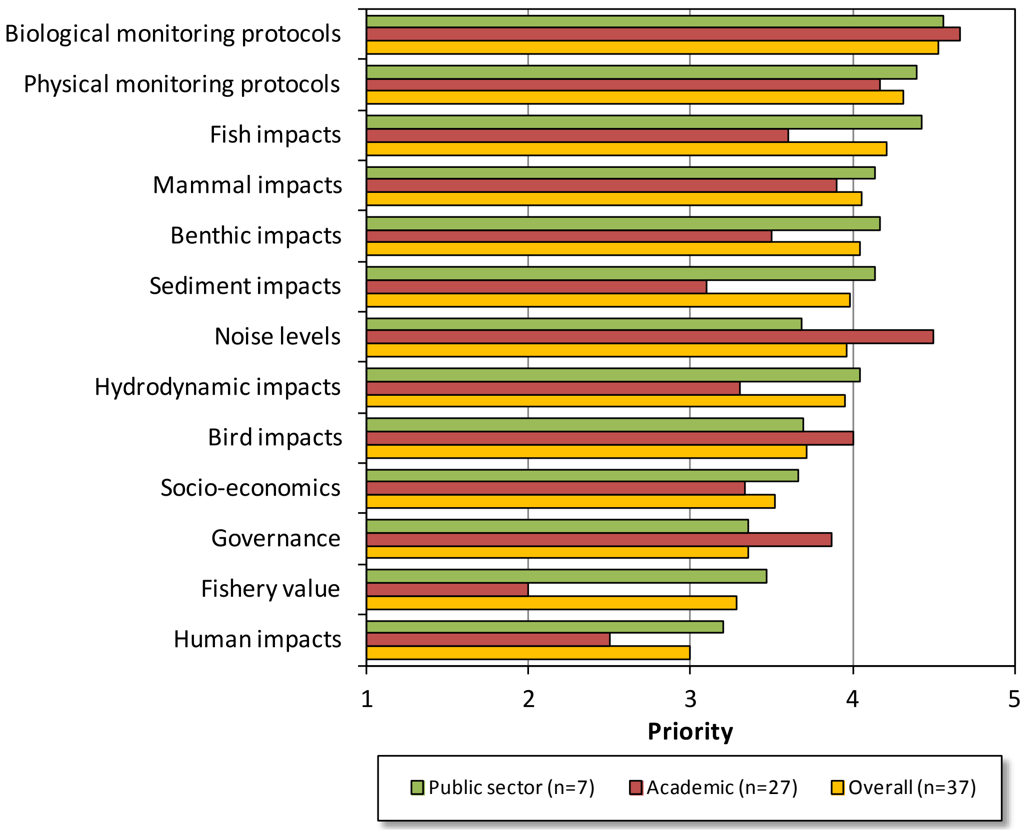

Figure 5.3. Priorities for transfer of findings of ecological and environmental research at wave and tidal energy test sites to full-scale developments, as scored by questionnaire respondents on a scale of 1 (low priority) to 5 (high priority). Responses by academic and public sector respondents are shown separately. The overall figures include responses from one marine renewable energy industry representative and two environmental consultants.

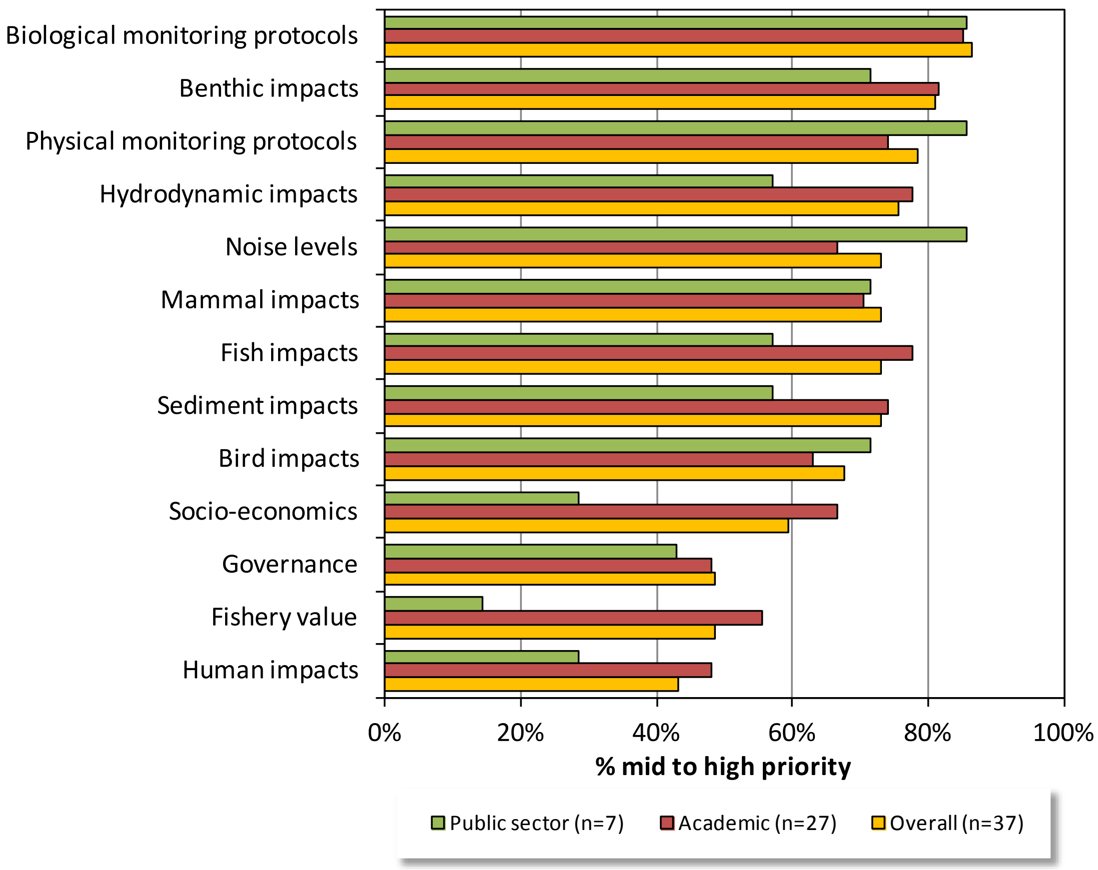

Figure 5.4. Priorities for transfer of findings of ecological and environmental research at wave and tidal energy test sites to full-scale developments: percentages of respondents scoring subject areas as mid to high priority (scores 3-5). Responses by academic and public sector respondents are shown separately. The overall figures include responses from one marine renewable energy industry representative and two environmental consultants.

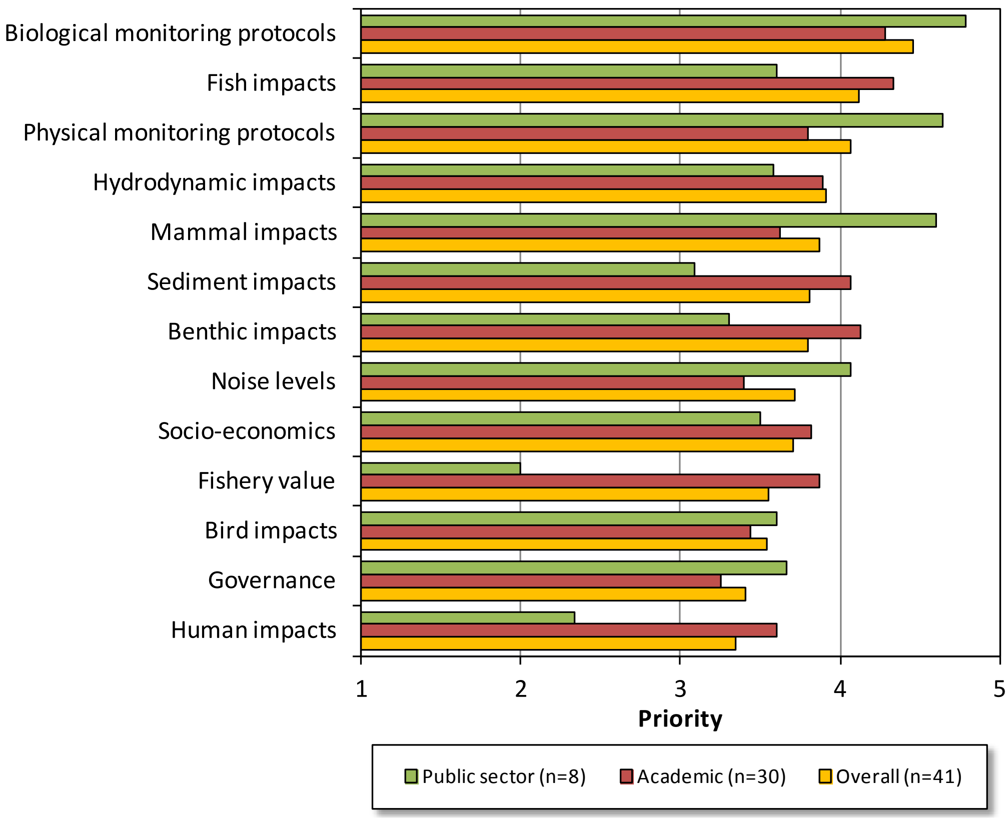

Figure 5.5. Priorities for gaps in ecological and environmental research that should be addressed at wave and tidal energy test sites, as scored by questionnaire respondents on a scale of 1 (low priority) to 5 (high priority). Responses by academic and public sector respondents are shown separately. The overall figures include responses from one marine renewable energy industry representative and two environmental consultants.

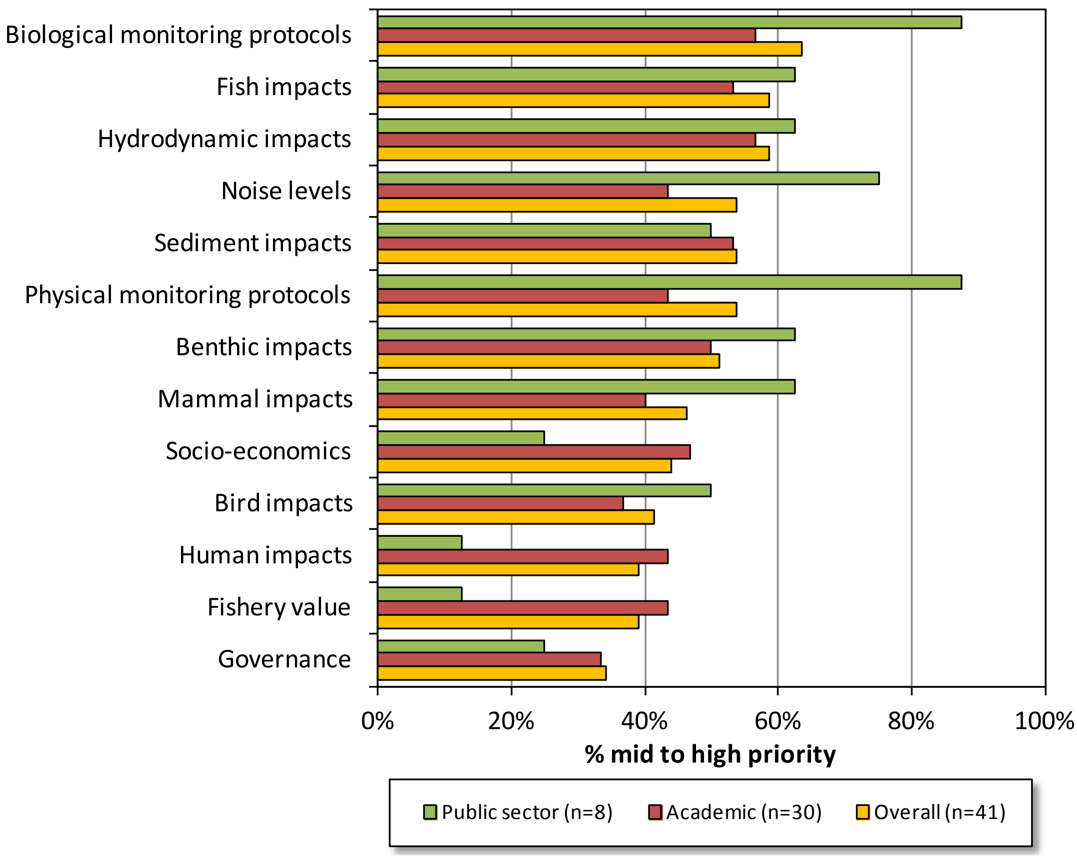

Figure 5.6. Priorities for gaps in ecological and environmental research that should be addressed at wave and tidal energy test sites: percentages of respondents scoring topics as mid to high priority (scores 3-5). Responses by academic and public sector respondents are shown separately. The overall figures include responses from one marine renewable energy industry representative and two environmental consultants.

Table 5.1. A list of wave and tidal energy test sites known to WKWTETS questionnaire respondents, with information on deployments and research activities.

Site	Type	Country	No. responses	Deployments	Comments on general applicability of research
EMEC (full-scale and nursery sites)	Wave & Tidal	UK-Scotland	26	Wave: Pelamis, Oyster, Penguin, Powerbuoy, Albatern, Seatricity Tidal: Open Hydro, Hammerfest Strøm, Voith, Atlantis, TGL, Scotrenewables, Blue Water	Monitoring of non-native species on renewables structures Testing activities key to commercial deployments Device survivability Technological development Grid connection Research outcomes generally applicable where available: Scottish Government/SNH/EMEC-funded research and monitoring generally available, developer-led impact monitoring less accessible but generally relevant Results most appropriate to similar technology applications elsewhere, but also able to generate generic understanding about interactions Proof of technology Installation impacts Recovery of sites post installation Noise Interactions of birds and fish with devices
Wave Hub	Wave	UK-England	15	None yet, but coming soon	Development planning Grid connection Array interactions Floating wind turbines possible in future Public perception studies Wave transmission modelling Sediment transport Benthos Socio-economics
Bay of Fundy (FORCE)	Tidal	Canada	10	Open Hydro	Very applicable research, especially on ecosystem level Device survivability High applicability for commercial scale tidal devices

Site	Type	Country	No. responses	Deployments	Comments on general applicability of research
Oregon	Wave	USA	6	OPT Powerbuoy, Wet NZ	Device survivability Technological development Grid connection
Strangford Lough	Tidal	UK-Northern Ireland	4	MCT Seagen	Generally applicable research Power output Mammal collision risk Birds Hydrodynamics
Admiralty Inlet, Washington	Tidal	USA	4	Open Hydro	Generally applicable research priorities Typical tidal energy site, research highly applicable to other areas Hydrodynamic and acoustic monitoring
Ramsey Sound	Tidal	UK-Wales	3	Deltastream, due spring 2013	Results to be widely disseminated for benefit of entire industry Test deployments will provide information on direct interactions between devices and mammals under closely monitored conditions Baseline monitoring Knowledge of environment faced by turbine
Lysekil	Wave	Sweden	3	Point absorber	Results published in international journals
Hawaii	Wave	USA	3	OPT Powerbuoy	Grid connection Deep-water anchoring
SEM-REV	Wave	France	3	?	Grid set up for wave energy converter tests Monitoring devices in place for monitoring and testing
Wave Energy Centre / Ocean Plug	Wave	Portugal	3	Pelamis	
Co. Galway	Wave	Ireland	3	OE Buoy	
FaBTest	Wave	UK-England	3	In process of establishment	
Wellington	Wave	New Zealand	2	Wet NZ	
Biscay Marine Energy Platform	Wave	Spain	2	Underway	
PLOCAN	Wave	Spain-Canary Islands	2	?	

Site	Type	Country	No. responses	Deployments	Comments on general applicability of research
Bay of Fundy (Fundy Tidal Inc.)	Tidal	Canada	1	Vertical axis turbine	Low applicability – technology specific
Pico Pilot Plant	Wave	Portugal-Azores	1	OWC	
East River, New York	Tidal	USA	1	Verdant Power	
Co. Mayo	Wave	Ireland	1	None yet	
Mutriku	Wave	Spain	1	Breakwater plant	
Paimpol-Bréhat, Brittany	Tidal	France	1	Open Hydro	Interactions between turbine and environment
Cobscook Bay, Maine	Tidal	USA	1	Crossflow turbine anchored to bottom	Initial test phase
Islay	Wave	UK-Scotland	1	WaveGen	Long-term prototype testing
West coast of Australia	Wave?	Australia	1	?	
Sandy Cove	Wave	Canada	1	Wave device	Low applicability – technology specific
Canoe Passage, British Columbia	Wave	Canada	1	Wave device proposed for 2012	Low applicability – technology specific
JMEC	Wave & Tidal	Japan	1	In process of establishment	
Narec	Wave & Tidal	UK-England	1	Device R&D	
Hirtshals	?	Denmark	1	?	
St Lawrence River, Québec	Tidal	Canada	1	Verdant array to be completed 2012	

Table 5.2. Profile of baseline data collection at wave and tidal energy test sites: numbers of questionnaire responses indicating collection of data of each type. Sites are listed in descending order of response numbers.

Site	Type	Physical environment	Mammals	Fish	Birds	Benthos	Human use
EMEC	Wave & Tidal	19	17	10	16	11	5
Wave Hub	Wave	9	5	5	5	4	4
Bay of Fundy	Tidal	4	3	3	2	2	
Ramsey Sound	Tidal	2	3	3	2	2	2
Strangford Lough	Tidal	2	3	2	2	2	1
Admiralty Inlet	Tidal	2	2	1	1	1	
Lysekil	Wave	1	1	2		2	
BIMEP	Wave	1	1	1		1	1
Oregon	Wave	1	1	1	1	1	
Paimpol-Bréhat	Tidal		1	1	1		1
Cobscook Bay	Tidal	1		1			1
East River	Tidal			1			
Overall		42	37	31	30	26	15

Table 5.3. Profile of marine environmental research at wave and tidal energy test sites in terms of relevance to impacts and opportunities: numbers of questionnaire responses indicating relevant research of each type. Sites are listed in descending order of response numbers.

Site	Type	Mammal impacts	Bird impacts	Fish impacts	Hydrodynamic impacts	Benthic impacts	Sediment impacts	Fishery impacts	Biodiversity benefits	Recreational impacts	Fishery management	Fishery stock enhancement
EMEC	Wave & Tidal	16	14	6	8	9	7	4	5		1	1
Wave Hub	Wave	3	5	6	6	5	5	7	4	6	4	3
Bay of Fundy	Tidal	3	2	3	2	2	1	2		1		
Ramsey Sound	Tidal	2	2	1	1	1	2		1	1		
Lysekil	Wave			1		1	1	1	1		1	1
Admiralty Inlet	Tidal	2		1	2		1	1				
BIMEP	Wave			1	1	1	1	1		1		
Oregon	Wave	1	1	1	1	1	1					
Strangford Lough	Tidal	2	1	1	1							
Cobscook Bay	Tidal			1	1			1		1	1	
Paimpol-Bréhat	Tidal			1								
Overall		29	25	23	23	20	19	17	11	10	7	5

Annex 1: WKWTETS List of Participants

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Annex 2: WKWTETS Programme

The following is an extract from the EIMR 2012 programme (30 April – 4 May 2012), which included WKTETS during 3 May 2012. Programme items specific to WKWTETS are given in black type.

Thursday, 3 May 2012

08.30 – 10.00 **Marine Renewable Energy Resources (cont'd)**

Session Chair: Dr David Woolf

Keynote Speaker: Dr John Huckerby, Chair of the Executive Committee of the International Energy Agency's OES

An International Vision for Ocean Energy

Dr Susana Baston, Heriot-Watt University

Modelling tidal flow in the Pentland Firth

Arne Vögler, Lews Castle College, UHI

Hebridean Wave-Power: Understanding the resource

Dr Andrew Dale, Scottish Association for Marine Science

The interaction between a tidal race and its low energy surroundings

Ben Timmermans, University of Southampton

Uncertainty in wave model prediction of WEC generated wave power

10.00- 10.15 Coffee

10.15 – 12.00 **Introduction to WKWTETS**

Session Chair: Dr Douglas Watson

Henry Jeffrey, The Institute for Energy Systems

The European Energy Research Alliance (EERA)

Daniel Wood, Centre for Environment, Fisheries and Aquaculture Science

Designing Turbines to comply with Environmental Legislation: De-risking the Consenting Process

Dr Mike Bell, International Centre for Island Technology

Background to WKWTETS and ICES SGWTE

Keynote Speaker: Matthew Finn, European Marine Energy Centre

The EMEC Story

Dr Graham Daborn, Acadia University, Nova Scotia

Tidal Power from the Bay of Fundy, Canada: Environmental and Socio-economic Considerations

Discussion

Presentation of poster prize

13.00 – 14.00 Lunch and Posters

14.00 – 15.45 **WKWTETS**

Session Chair: Dr Mike Bell

Keynote Speaker: Dr Roland Cormier

Ecosystem-Based Risk Management

Dr Carol Sparling, Sea Mammal Research Unit, University of St Andrews

Monitoring marine mammals at the world's first operational scale tidal energy device

Andrew Want, ICIT, Heriot-Watt University

Monitoring Orkney's High-Energy Littoral Environment: Photographic and Image Analysis Methodologies for Quantifying Species and Biotope Coverage

Garrett Staines, University of Maine

Assessing effects of tidal hydrokinetic devices on fishes at deployment and ecosystem scales

Dr Beth Scott, University of Aberdeen

Seabirds and marine renewables: Are we asking the right questions?

Discussion

15.45 – 16.00 Coffee

16.00 – 17.45 **WKWTETS** (cont'd)

Session Chair: Dr Mike Bell

Sue Barr, OpenHydro

Short-term Temporal Behavioural Responses in Pollack, Pollachius pollachius, to Marine Tidal Turbine Devices; a Combined Video and ADCP Doppler Approach

Dr Jennifer Norris, EMEC

Environmental monitoring at EMEC

Andrea Copping, Pacific Northwest National Laboratory

Getting Devices in the Water - Understanding Environmental Effects of Marine Energy Development in the US

Davide Magagna, University of Plymouth

Gathering the perspectives and experience from test sites and device developers for Environmental and Socio-economic Impact Assessment of Wave Energy

Discussion

Summarizing Presentations: Dr Gareth Davies, Aquatera, James Mowat, MTDS Ltd

Priorities for research into marine energy – past, present and future - the importance of working together

17.45 Closing Comments by Dr Mike Weston

Annex 3: Rapporteur notes from workshop presentations

Mike Bell, Introduction to WKWTETS and SGWTE

- Questionnaire distributed to attendees – idea is to establish what we have learned so far from wave and tidal energy test sites.
- Objectives:
  - Collate information on test sites and how they are being used;
  - Describe environmental research that is being undertaken alongside devices / in test sites;
  - Identify research gaps that should be addressed at test sites and how current research findings can be transferred to full-scale developments.

Matthew Finn, The EMEC story

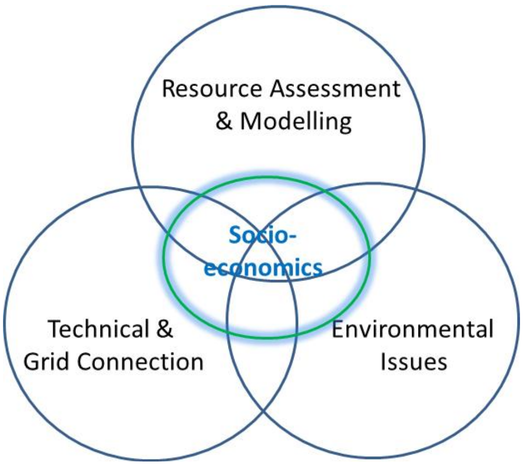
- The only accredited test site
- Comprehensive overview of testing activities going on at EMEC
- EMEC has been involved in the development of 12 UK Industry standards – 6 of these are being taken forward through the work of IEC TC114;
- Already 529 employed in marine energy in Scotland with 250 in Orkney;
- Priority now is to get metal wet and to find out what works for how long.

Implications for ICES SGWTE

- *How can standards for devices reflect compliance with environmental management requirements?*

Graham Daborn, Tidal power from the Bay of Fundy, Canada: Environmental and socio-economic considerations

- Need experience in the overlapping areas:



- Also need to recognize that all the issues are under-pinned by socio-economic considerations.
- FORCE Test Centre and FERN Research Network. Latter is focusing on 4 key areas: 1. Hydrodynamics, 2. Biology/Ecology, 3. Engineering challenges and 4. Socio-economics.
- Community development aspects of marine renewables are really important. In Nova Scotia there are two tariffs: one normal 'FIT' for large-scale industrial development and a second one 'COMFIT' which supports smaller scale community owned development that is also supported by Government.

Implications for ICES SGWTE

- *FERN work to inform research gaps work?*
- *Consider the need to look at socio-economics in a more systematic manner.*

Roland Cormier, Ecosystem-based risk management

- Need to translate all the science into useable format for policy-making / decision-making and ultimately into effective management controls.
- Idea was to position EIA into a risk management framework namely ISO31000.
- First step in the process was to establish the context – this is critical so as to facilitate ecosystems based management.
- Need to be careful with the terminology we use and how this can be interpreted differently by different groups/users etc.
- Need to define what is acceptable and what is not acceptable – they formulated a matrix and attributed values to the risk impact levels, which according determines how they ask the questions to scientists, other policy-makers, etc.
- Need to think about how we define 'impact'. In Canada, for example, this is defined (Habitat Risk) and categorized as disruption, harmful alteration or destruction.
- Want to end up with an environmental risk profile and develop management options from this. You end up with a range of options and a matrix with an associated narrative / explanation.
- Then you decide where along the pathway can you implement a management control.
- We really need to be monitoring the effects of a management measure to see if it is effective rather than monitoring actual environmental parameters. This is why a review of management is critical after a certain period of time – usually 5 years. It needs to be adapted if problems are identified.
- Assessing and describing impacts is not sufficient – this must be brought into the management framework.
- The focus should be on what aspect of a given activity should be managed and how.
- Need to align risk assessment results with risk criteria.
- We need the best science and technical knowledge and advice to inform management decisions.
- Also need to focus management strategies and resources to priorities of highest ecosystem, socio-economic and policy risk.

Implications for ICES SGWTE

- *Can we frame the EIA process in a risk management framework? – should we be thinking about this?*
- *What are the highest ecosystem, socio-economic and policy risks? – make these our priority areas.*

Carol Sparling, Monitoring marine mammals at the world's first operational scale tidal energy device

- Environmental monitoring programme implemented in Strangford was adapted to local specificities as there were lots of [perceived] uncertainties.
- Had a science group chaired by an independent scientist and also a liaison group to translate this information into a digestible format for stakeholders.
- Scale is important – need to pick up both temporal and spatial scales.
- Need reliable baseline data so as to be able to compare findings and decipher trends (if any).
- All the data (6 years) from SeaGen has told us that:
    - A single device in a narrow channel is not a barrier to seal or porpoise movement;
    - Installation activities may cause temporary displacement of porpoises but this is not a permanent effect/impact
    - Can be some local avoidance / redistribution – value of additional regional information/data.

- We have not learned:
  - Anything about evasion / nearfield avoidance behaviour as the device had to be shutdown once a creature came within a specified distance;
  - Whether small-scale behavioural changes lead to significant impacts at individual/population/ecosystem level long term;
  - Multiple devices – can we scale up?;
  - Animal responses to devices in a more open environment.
- We need to develop the ability to determine the consequences of observed effects – just how significant are they?

Implications for ICES SGWTE

- *There is a high degree of natural variation in behaviour, abundance and distribution of marine mammals – this requires large sample sizes and good baseline characterization to have the ability to detect change and/or fully characterize population.*
- *A regional focus is important – should we / can we list transnational projects as well as national research activities or are these already reflected?*
- *A multi-scale approach to monitoring helps to reduce uncertainties about impacts but cannot be repeated at all sites – how do we deal with such uncertainty?*
- *Should the SGWTE try to catalogue what is collected by State agencies on a regular basis, especially in light of Marine Strategy Framework Directive requirements?*

Andrew Want, Monitoring Orkney's high-energy littoral environment: Photographic and image analysis technologies for quantifying species and biotope coverage

- Main question is whether removing energy by deploying wave energy converters produce observable changes on rocky shores.
- Trying to determine this through littoral, sublittoral and cliff surveys.
- Have done sublittoral transects along Vestra Fiold which is a potential landfall location for cable in future.
- Have combined sidescan and bathymetric data with ground-truthing to map geomorphology, species and biotopes.
- Littoral monitoring of five sentinel species and looked at their north and south distribution limits.
- Working on barnacle recognition software.

Implications for ICES SGWTE

- *Must take cognisance of broader global environmental change and climate change when looking at the results of environmental monitoring. This must also be reflected in baseline environmental data / information.*

Garrett Staines, Assessing effects of tidal hydrokinetic devices on fishes at deployment and ecosystem scales

- Looked at direct and indirect effects on fisheries.
- Cobscook Bay – just inside Bay of Fundy.
- BACI methodology.
- When looking at indirect effects they employed a Simrad single beam echosounder and DIDSON acoustic camera which can penetrate 10-12m into water column.
- They were looking for seasonal patterns in fish density and vertical distribution (for middle to middle top of the water column).
- They carried out this work before device deployment and will continue to do so following device installation. Will combine the previous methods with a side-looking component so as to provide 24/7 hydroacoustics.
- When looking at direct effects they placed two cameras to the fore and aft of the device.
- Results show a big spike in fish at slack tide when you would expect the turbine to be still.
- The fish recorded were very small (<10cm).

- In 2011 they had 175 sampling events, 4 gear types and captured 5965 fish from different habitats.

Implications for ICES SGWTE

- *Real device / environment interactions – is this something to be advocated at test sites?*

Beth Scott, Seabirds and marine renewables: Are we asking the right questions?

- Focus at the moment is not correct – we should be asking about foraging and the energetics of foraging (costs of change).
- Habitats change frequently.
- We need to develop new methods to rapidly understand how marine renewable energy devices will have effects on seabirds and marine mammals.
- Tagging studies are good and we can learn a lot from them about site fidelity and general foraging habits. Tags have also improved greatly – much smaller, easier to use.
- Need to understand foraging habitat and behaviour at a local scale as well.
- Can we do very rough estimates of risk collision and calculate the impact this would have on a population of a particular species and concentrate efforts on those at most significant risk?
- Need to quantify the physics that these birds use to forage – two NERC funded projects on this: FLOWBEC and RESPONSE.
- Working with OpenHydro at EMEC and with WaveHub to do more monitoring work using multibeam.

Implications for ICES SGWTE

- *Research on seabirds should focus on foraging behaviour and energetics.*
- *Scale is important and should be reflected in any future projects.*
- *Reflect the objectives of both FLOWBEC and RESPONSE in the SGWTE report.*

Sue Barr, Short-term temporal behavioural responses in Pollack, Pollachius pollachius, to marine tidal turbine devices: a combined video and ADCP Doppler approach

- OpenHydro have had a tidal device at EMEC since 2006.
- Looked at short-term temporal behavioural responses in Pollack to marine tidal turbine devices using a combined video and ADCP approach.
- Lack of background data/knowledge of specific ecological interactions with tidal energy devices.
- Gaps in ecological baseline information at tidal energy development sites.
- Need to develop methodologies for carrying out such surveys/studies.
- Interested in collision and entrapment.
- Have 261 hours of video footage.
- GAM results suggest that fish abundance is related to the velocity rate – true for both years.
- Fish feed behind the turbine, against current flow.
- Want to extend the study to include different methods and equipment and also seasonal and temporal abundance of fish.
- All the technologies are different therefore the methodologies employed have to be different.
- Need to extend the time-scales.
- Also interested in marine mammals and underwater noise.

Implications for ICES SGWTE

- *Lack of background data/knowledge of specific ecological interactions with tidal energy devices.*
- *Gaps in ecological baseline information at tidal energy development sites.*
- *Need to develop and/or refine methodologies for carrying out such surveys/studies at sites where different technologies and devices are to be deployed.*

- *Seasonal and temporal considerations should be reflected in all studies.*

Jenny Norris, Environmental monitoring at EMEC

- Key is to have developer-led research.
- Licensing set up at EMEC is somewhat unique (facilities are licensed, not always necessary to carry out full EIA – this is size dependent).
- Focus on monitoring sensitive species, collision, device noise etc.
- Main driver for monitoring is regulatory:
    - Data provision and assessment of environmental risks;
    - Potential for displacement of / harm to sensitive species;
    - Effects due to physical presence or outputs from device.
- Assessment of monitoring reports is essential to refine the [future] licensing conditions.
- ReDAPT project funded by ETI focuses on environmental monitoring. This will have a Cost of Energy (CoE) assessment element as well as a lot of environmental monitoring. For the latter a range of techniques will be employed: active sonar, acoustic, camera, marine radar, ROV, CTD/turbidity, biofouling: benthic lander and test panels. The data will be provided in as near to real-time as possible and via wireless technology. Cables are being installed at the moment. Final reporting due in 2014. ETI will share the results.
- EMEC try to identify research projects with a "generic" element: the resource, the receiving environment, etc.
- They take a collaborative approach so as to cover wider elements.

Implications for ICES SGWTE

- *Key is to have developer-led research.*
- *Regulatory environment still drives the environmental monitoring to be carried out at a site.*
- *Inclusion of REDAPT project in the ICES SGWTE tables.*
- *Focus on priority areas like collision risk, sensitive species and noise.*
- *Ensure projects are collaborative so as to address as many elements as possible.*

Andrea Copping, Getting devices in the water – understanding environmental effects of marine energy development in the US

- In the US they have no test centres.
- The role of the national laboratories is to accelerate deployment of marine hydrokinetic devices in an environmentally responsible manner.
- Their approach to this is to set risk-based priorities by examining stressor-receptor interactions – through the ERES framework.
- The results of this work are available through a dedicated database known as Téthys.
- They have identified the following gaps in knowledge:
    - *EMF.* No standardized methods for assessing EMF exposure. They have borrowed the methods they used from toxicology (Helmholz Coil, 500lb copper) and exposed salmon, halibut and crab to one energised coil and not the other so as to replicate a cable. Results suggest decreased growth at larval stage in the halibut. Want to broaden this study to look at American lobster and elasmobranchs.
    - *Acoustics.* For these experiments they have used salmon as they are not allowed to experiment on marine mammals. Basically they recreate noise and expose salmon to it (Chinook salmon). They used noise data from EMEC (OpenHydro) as they had none of their own. No hearing loss indicated but salmon has a swimbladder. Statistically significant low levels of tissue damage observed. Now want to expose other species of fish to noise (e.g. rockfish).

- o *Strike analysis.* This was a unique situation involving an Orca (resident) population off the west cost of the USA. Orca are highly endangered and a NOAA responsibility under Endangered Species/Wildlife legislation. They had no site-specific data on behaviour. Results indicated that orca spend less than 3% of their time in waters deeper than 30m. The proposed OpenHydro turbine was to be located at 55m. They modelled the turbines and created a rubber orca (crash test orca!) to see how it would interact with the turbines. An absolute worst case scenario, if you will, resulted in what we would consider a bruise. The results of this experiment have been submitted to the regulator (NOAA) but no response has been received back from them.
- Now they would like to look at behaviour change and interactions of other animals with tidal turbines.
- In the US the regulators have given the national laboratories a specific question which they have then tried to address.

Implications for ICES SGWTE

- *There are still countries that have no test sites but are still carrying out [pertinent] environmental research, such as the US*
- *Research questions are based on risk-based priorities by examining stressor-receptor interactions.*
- *The research questions are set by the regulators.*
- *Are laboratory experiments equally as important as field experiments/studies?*
- *Important to make the results of all research available (e.g. through a database).*
- *US scientists have focused on EMF, Acoustics and Strike.*
- *Note that some methods are still not established/tailored to marine renewables.*

Davide Magagna, Gathering the perspectives and experience from test sites and device developers for environmental and socio-economic impact assessment of wave energy

- SOWFIA project looks at the lack of consistency in the application of Environmental Impact Assessment in test sites across Europe.
- Need to begin moving from generating lots of data from environmental monitoring studies to developing guidance/guidelines for developers.
- Also need to learn from other industries – burden seems to be heavier on wave and tidal energy developers.
- Important to bring stakeholders along in the process – consultation mechanisms in most jurisdictions have been deemed fit-for-purpose by the developers but stakeholder groups feel differently.
- Example of FLOWW in the UK – Fisheries Liaison with Offshore Wind and Wave group.

Implications for ICES SGWTE

- *Different procedures exist in different locations across Europe despite a common EU legal framework – is this due to site-specific considerations or more stringent application of legislation by some Regulators?*
- *Is there value in looking at the burdens on other marine industries?*
- *Can we start producing guidance for the environmental effects we know most about?*

Question and Answer session

Key topics considered include:

- Is there a danger that too many groups are trying to identify research activities and gaps e.g. EERA Joint Programme on Ocean Energy; ICES SGWTE, NERC/national initiatives, IEA OES Annex IV?
- Who is driving the idea of combined uses and why?
- What are the issues surrounding decommissioning and why? Can't we re-use structures?

- What are the advantages / disadvantages of the conventional approach compared with a risk-based approach?
- What are the effects and impacts of Climate Change / Global Environmental Change and how these are reflected/taken into account in baseline studies?
- Is climate change driving support for marine renewable energy development?
- What cues are the foraging birds looking for?
- Where do fish go when they are displaced from development sites? Do fish always aggregate downstream of devices? What about daytime/night-time differences? Do the fish actually go through the turbine?
- How do we address connectivity in birds and fish species at a global scale?
- Where are there gaps in test sites? Do we have what we need? Is it just a case of better integration / more joined-up approach?
- How do we determine the tipping points? Can we?

Annex 4: WKWTETS Questionnaire

WKWTETS – ICES Workshop on Wave and Tidal Energy Test Sites

What have we learned from the wave and tidal energy test sites so far?

Reduced- and full-scale devices for extracting hydrokinetic energy from waves and tides are being tested at a number of sites worldwide. Research being undertaken alongside these test deployments is being used to provide environmental and biological baselines and monitoring methods and to determine the likely environmental and ecological consequences of commercial-scale wave and tidal energy developments. It is timely to ask: what have we learned so far? and what do we still need to learn? Your participation in WKWTETS is being sought to gather information on the nature of wave and tidal energy test sites, how they are being used for test deployments and environmental research and on the scope for the outcomes of this research to be applied in the environmentally-sustainable development of the wave and tidal energy industry. Information is organised under three Terms of Reference for the Workshop. Please tell us what you know!

Your information:

Name:		**E-mail address:**	
Organisation:		**Role in Organisation:**	
Are you happy for your name to be included in the list of workshop participants?	Y/N	**Do you want to receive a copy of the workshop report by e-mail?**	Y/N
Are you involved in wave and tidal energy testing activities?	Y/N	**Are you involved in research or monitoring at wave and tidal energy test sites?**	Y/N
Nature of interest in wave and tidal energy (tick all that apply):			
Sustainable energy supply		Marine engineering	
Investment opportunities		Impacts on physical processes	
Commercial development		Ecological interactions	
Device development and testing		Fishery interactions	
Consenting and regulation		Interactions with other marine stakeholders	
Marine Spatial Planning		Community benefits	
Other (please specify)			
Other (please specify)			
Other (please specify)			
Other (please specify)			

Please place completed questionnaire in box at back of the lecture theatre, or send to Dr Mike Bell, ICIT, Heriot-Watt University, Stromness, Orkney KW16 3AW, UK (m.c.bell@hw.ac.uk). Please feel free to leave any sections blank if you would prefer not to provide information. *Thank you!*

WKWTETS – ICES Workshop on Wave and Tidal Energy Test Sites

ToR a) Collate information on wave and tidal energy test sites worldwide, cataloguing current and projected future device deployments and identifying site and device features that will allow research findings with respect to potential environmental impacts and interactions to be generalised across other sites and developments

Please tell us about wave and tidal energy test sites that you are aware of:

Name of test site	Country	Test deployments	General applicability of research outcomes

WKWTETS – ICES Workshop on Wave and Tidal Energy Test Sites

ToR b) Describe ongoing marine environmental research being undertaken along-side device testing activities at wave and tidal energy test sites and report on scientific findings with regards to potential impacts and opportunities

Please tell us about any marine environmental research that you are aware of being undertaken at wave and tidal energy test sites:

Test site	Research activity	Baseline data collection		Relevance to impacts & opportunities			
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	
		Physical environment		Hydrodynamic impact		Fishery impacts	
		Benthos		Sediment impact		Recreational impacts	
		Fish		Benthic impact		Biodiversity benefits	
		Birds		Impacts on fish		Fishery management	
		Mammals		Impacts on birds		Fishery stock enhancement	
		Human use:		Impacts on mammals		Other:	

WKWTETS – ICES Workshop on Wave and Tidal Energy Test Sites

ToR c) Provide a list of priorities for applying research findings and monitoring methods developed at test sites to full-scale commercial deployments, identifying crucial research gaps that are most urgent to address at the test sites before upscaling of commercial wave and tidal energy developments

Tell us about your priorities for transferring findings of environmental and ecological research at test sites to full-scale developments:

Research topic		Priority: Low 1	2	Mid 3	4	High 5	Comments on how findings should be transferred
Biological monitoring protocols							
Physical monitoring protocols							
Hydrodynamic impacts							
Sediment impacts							
Benthic impacts							
Fish impacts							
Bird impacts							
Mammal impacts							
Noise levels							
Fishery value							
Human impacts							
Socio-economics							
Governance							
Other:							
Other:							

What are the crucial research gaps that should be addressed at wave and tidal energy test sites?

Research topic		Priority: Low 1	2	Mid 3	4	High 5	Comments on what is currently lacking
Biological monitoring protocols							
Physical monitoring protocols							
Hydrodynamic impacts							
Sediment impacts							
Benthic impacts							
Fish impacts							
Bird impacts							
Mammal impacts							
Noise levels							
Fishery value							
Human impacts							
Socio-economics							
Governance							
Other:							
Other:							