NATURAL ENVIRONMENT RESEARCH COUNCIL

Wave & Tidal Consenting Position Paper Series

Marine Mammal Impacts

AUTHORS

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Contents

"To review key experience and provide stakeholders and industry alike with a consolidated understanding of, and consensus on, the current state of knowledge relating to potential environmental impacts associated with marine renewables and marine mammals"

1 Background

The main potential impacts of wave and tidal energy devices ('wave and tidal devices') on marine mammals have previously been identified and described by numerous studies and impact assessments. Detailed descriptions of the key potential impacts and the assumed mechanisms underlying them have, for each technology, been reported extensively elsewhere (Faber Maunsell & Metoc, 2007; Dolman and Simmonds, 2010; MacLeod et al., 2012; Sparling et al., 2012; Aquatera, 2012; and Thompson et al., 2013).

The aim of this paper is to review key experience and provide stakeholders and industry alike with a consolidated understanding of, and consensus on, the current state of knowledge relating to potential environmental impacts associated with marine renewables and marine mammals.

This paper also uses the experiences of those involved in the wave and tidal energy industry (gathered by telephone interview) to highlight issues that have arisen during the development of wave and tidal technologies.

Table 1 summarises the number of full-scale devices installed or currently operating in the UK, where 3.4MW is installed for wave and 5.2MW for tidal projects.

TABLE 1. FULL SCALE DEVICES INSTALLED OR CURRENTLY OPERATING IN UK WATERS

DEVICE TYPE	OPERATOR	DEVICE	RATING (MW)	COMMISSIONED	LOCATION
TIDAL	Andritz Hydro Hammerfest	HS1000	1	2011	Fall of Warness, European Marine Energy Centre ('EMEC')
	Alstom	DeepGen 1MW	1	2013	Fall of Warness, EMEC
	Marine Current Turbines	SeaGen	1.2	2009	Strangford Lough, Northern Ireland ('NI')
	Minesto	Deep Green	0.5	2013	Strangford Lough, NI
	OpenHydro	Open Centre turbine	0.25	2008	Fall of Warness, EMEC
	Scotrenewables Tidal Power	SR250	0.25	2011	Fall of Warness, EMEC
	Voith Hydro Ocean Current Technologies	Hy Tide 1000-13	1	2013	Fall of Warness, EMEC
WAVE	Aquamarine Power	Oyster 800	0.8	2012	Billia Croo, EMEC
	Fred.Olsen	Bolt "Lifesaver"	0.25	2012	FaBTest, Cornwall
	Pelamis	Pelamis P2	0.75	2010	Billia Croo, EMEC
	Seatricity	Oceanus	1	2013	Billia Croo, EMEC
	Wello	Penguin	0.6	2013	Billia Croo, EMEC

2 Key Issues

In the last 5 years the wave and tidal industry has seen a period of rapid expansion. Much of this activity has been developer led and has focused on the provision of environmental information and assessments, in order to gain consents, as well as the monitoring of environmental impacts in areas where devices (mostly test devices) have been installed. In addition, research, often undertaken by the academic community (e.g. Natural Environmental Research Council's ('NERC') Marine Renewable Energy Knowledge Exchange ('MREKE') research programme, Scottish and Welsh Government funded research), has also been on-going with a particular focus on developing methodologies, understanding marine mammals' functional use of high energy marine environments and measuring animals' responses to underwater noise. Long term studies at sites such as Strangford Lough and the European Marine Energy Centre ('EMEC') have been particularly valuable in allowing the monitoring of impacts and the development of methodologies.

"There is still uncertainty regarding the level of impacts that may arise from the construction, operation and maintenance phases of wave and tidal projects at a pre-commercial and commercial scale (both single devices and initial arrays)."

The research and monitoring that has been carried out to date across various sites and projects to inform these impacts is summarised in the Key Research: Impacts section, in this document. There is also a considerable amount of on-going research that will provide outputs that will aid the prediction and measurement of potential impacts during the Environmental Impact Assessment ('EIA') process. This research is outlined in Table 2.

There is still, however, uncertainty regarding the level of impacts that may arise from the construction, operation and maintenance phases of wave and tidal projects at a pre-commercial and commercial scale (both single devices and initial arrays). Although the application of the source-pathway-receptor model within the EIA process identifies the potential impacts, it is the assessment, understanding and quantification of the impacts that remains a key challenge. Whilst knowledge can be shared from other marine industries on impacts that are not specific to the wave and tidal industries, for example vessel activity, there remains a large amount of uncertainty around impacts that are specific to wave and tidal devices. Some of this uncertainty will remain, regardless of on-going research or monitoring of test devices, until monitoring results from more devices and larger installations become available. Although this uncertainty may be viewed negatively, ensuring that it is addressed in a constructive and co-ordinated fashion early in the development of the industry may avoid the uncertainty that continues to hamper the development of offshore wind. Addressing much of this uncertainty in the short term will also reduce future consenting risk, reduce regulatory burdens and reduce monitoring requirements in the future. This general position is common for both wave and tidal projects; however it is acknowledged that there are differences between (and within) these two types of generation at the level of individual impacts.

Current research programmes will provide vital information in the short-term, however to ensure momentum is not lost, further funding initiatives focused on the characterisation and quantification of environmental impacts are critical during the coming three to five year period. It is therefore recommended that the consenting and development of arrays around 10 megawatts ('MW') in size, or the phased deployment of larger arrays, should be fast-tracked to enable this critical learning to take place and to ensure that commercial scale development of the wave and tidal industry is not hampered by uncertainty. This recommendation supports the pragmatic policy of survey-deploy-monitor that has been developed by Marine Scotland.

> **"...these projects need to provide statistically robust impact monitoring studies with scientific and regulatory oversight to advance the industry position as a whole"**

In return, these projects need to provide statistically robust impact monitoring studies with scientific and regulatory oversight to advance the industry position as a whole. The ability to achieve robust monitoring outputs must be considered carefully for each site and studies should only be required and implemented where there is a reasonable probability of achieving this. Robust impact monitoring studies of single devices and early arrays will provide the industry with the opportunity to reduce consenting risk to future projects by ensuring that uncertainty is reduced sufficiently to avoid the prolonged precautionary approach that has been adopted by regulators during the deployment of both onshore and offshore wind (an approach most associated with Habitats Regulations Assessments ('HRA') under The Conservation of Habitats and Species Regulations 2010 (as amended) in England and Wales and The Conservation (Natural Habitats, etc.) Regulations 1994 (as amended) in Scotland). The key to the success of this will be to ensure that the design of the monitoring strategies are focused on answering specific questions (related to potentially significant impacts) and do not simply repeat the surveys undertaken to inform the consenting process.

Other key consenting issues identified through the current review of industry experience and that are considered important in ensuring the future success of the wave and tidal industry are:

- *Determining the priority questions that need to be answered to reduce uncertainty surrounding potentially significant impacts and accordingly determine the metrics that need monitored and quantified;*
- *Ensuring that the level of marine mammal survey effort required to inform post-consent impact monitoring is determined based on the outcomes of the EIA process and is focussed on potentially significant impacts (i.e. by following the source-pathway-receptor model to identify the questions that need to be asked) and that monitoring requirements are tailored to the specific questions for a given project;*
- *Ensuring that any standardisation of survey methodology enables comparative approaches but does not result in a 'one size fits all' approach discouraging the development of new and improved methodologies, nor detract from a project and site specific approach to survey design;*
- *Ensuring post consent impact monitoring surveys are fit for purpose, address specific pre-determined questions and have sufficient statistical power to detect real change. Consideration must be given to whether this is achievable for all potential impacts at the scale of each site, taking into account location, natural variation in marine mammal abundance and distribution. Where monitoring outcomes are considered to be unachievable there is no point requiring data collection with no clear outcome.*

3 Key Impacts

This section provides a summary of the current state of knowledge on impacts on marine mammals. Key impacts were determined from a combination of reviewing available research and monitoring studies, review of project specific scoping and EIA documents and information gathered during telephone interviews.

3.1. Collision

Tidal devices

The current approach to assessing whether collision risk is likely to be sufficiently common to warrant further investigation is by modelling (using a variety of models) the predicted encounter rate between animals and turbines based on the physical characteristics of the device's moving parts, estimates of local density of marine mammals (and basking sharks) or on their rate of passage past the turbine and their use of the water column and their physical characteristics (swim speed, size) (e.g. Wilson et al., 2007). For sites and species where interactions could be high, the approach taken to consenting in many sites to date has been to place an assessment of the estimated mortality as a result of collisions into the context of the size and health of the relevant population, to determine whether the predicted level of mortality could have the potential to significantly affect the status of the population, analogous to the assessment of bird collision risk with wind turbines using Population Viability Analysis ('PVA'). In practice to date this means that the predicted numbers of encounters have been compared to an allowable 'take' for the relevant population using a 'Potential Biological Removal' ('PBR') framework, similar to that used by the Scottish Government to issue licences to the fishing and aquaculture industry for seal control[1]. Other approaches may be taken in future, including the Population Consequences of Disturbance ('PCOD') approach which predicts future population change as a result of individual level impacts. Whichever method is chosen in assessments, there is a need to define what is an acceptable level of impact for each population. Current approaches apply a degree of pragmatism to allow consenting under uncertainty and also provide a useful framework for reducing this uncertainty with targeted data collection. There is currently no empirical evidence to inform how the likelihood of behavioural responses to devices (such as avoidance and evasion) should be taken into account, which is crucial in scaling these encounter rate estimates to determine true risk. Empirically derived rates of avoidance/evasion can then be applied to existing collision models to re-evaluate rates of interaction and together these can be used to evaluate the statistical power of post-deployment monitoring. No data have been collected to date on the fine scale (i.e. metres) avoidance or evasion abilities of marine mammals around operating marine renewable devices and understanding this is a priority. No marine mammals have been recorded in many hours of video monitoring of Open Hydro device while operational at EMEC but it is important to note that although useful, the monitoring was not specifically designed to determine the potential for marine mammal interactions and has a limited field of view. A trial period of operation without shut down mitigation at Marine Current Turbines' SeaGen has been licenced and monitoring will be put in place to measure encounter rates and monitor the behaviour of marine mammals around the operating device. Tidal Energy Limited's DeltaStream device has similarly been licenced for a 12 month deployment in Ramsey Sound, Pembrokeshire, without the need for shut down mitigation, but with monitoring in place for determining close range behaviour and empirical

> **"There have been no reports of any marine mammal collisions at any tidal devices to date"**

encounter rates. Once empirical data are available on encounter or passage rates, these can be compared with predicted rates to refine (and assess) the predictive modelling approach. This, together with evidence on evasion or avoidance provides an important feedback loop in the modelling and helps to move towards better parameterised models and evidence based consenting.

In current risk assessment models, the assumption is made that any collision results in mortality but very little information is available on the likely physical consequences to a marine mammal if there is an impact with a tidal turbine blade or other moving parts of a tidal device. The severity of any injury is likely to depend on the speed of collision. Computer modelling of an OpenHydro device suggests that it would not exert sufficient force to kill or severely injure an adult killer whale (US Dept Energy, 2012), but this device does not have exposed tips present in other designs. Marine Current Turbines has commissioned a similar study for its SeaGen device.

The ability to detect collision is an important issue. As far as we are aware, no effective methodologies have been developed or demonstrated in realistic field conditions. This is extremely challenging and currently no monitoring technique has been shown to be able to categorically determine whether a collision occurred. There have been no reports of any marine mammal collisions at any tidal devices to date, however it is important to note that unless appropriate monitoring is in place, the absence of evidence of an impact is not the same as evidence of no impact. This is particularly important in a HRA context where the onus is on the developer to prove there will be no adverse effect on integrity. Therefore it is critical that empirical data on close range encounter rates and behaviour of marine mammals around operating turbines are available to refine collision probabilities. Similarly a lack of carcasses around an operational device is not sufficient evidence that there have been no collisions, unless modelling suggests a strong possibility that a high proportion of any carcasses will be recovered in the vicinity of the development. Researchers at the Scottish Association of Marine Science ('SAMS') and at Queens University Belfast ('QUB') are currently modelling predictions of where carcasses might end up and this will help determine the utility of carcass surveys.

3.2. Collision with vessels – "corkscrew seal injuries"
both Wave and Tidal but primarily during installation phase

Recent events in UK waters suggest that seals may be being killed by collisions with ships with ducted propellers (Thompson et al., 2010; Bexton et al., 2012). Although the circumstances and conditions under which such fatal interactions occur are as yet unknown, it is likely that deployment and operation of wave and tidal devices will increase the amount of shipping activity in areas that may be important foraging sites for seals and cetaceans. Therefore there is potential that any such harmful interactions could increase, depending on the type of vessel used. This is primarily a shipping issue, and is not restricted to wave and tidal devices, although many wave and tidal developments are likely to use ducted propeller vessels during installation, maintenance and decommissioning so this issue is of direct relevance to the wave and tidal sector. To date there is insufficient information to be able to estimate the scale of the problem or identify when or where these problems will arise. Despite current uncertainties about the mechanism and scale of impacts, the requirement for mitigation should be assessed using a project and location specific risk assessment.

3.3. Entanglement
Primarily Wave Energy Converters and 'tethered' tidal devices

The potential for entanglement will vary with animal size and the degree of the tension/rigidity in the mooring lines and cables. There is a great deal of uncertainty about the potential for impact but slack lines are assumed to pose a greater risk than taut ones and therefore there is potential to mitigate by design. Given the global marine mammal-fishing gear by-catch issue, entanglement of lost fishing nets/ropes in wave and tidal devices is probably a greater risk to marine mammals than animals fouling in the devices themselves. Although no instances of any entanglement of marine mammals with mooring systems or 'lost' fishing gear associated with mooring systems have been reported to date. As part of a consortium with the University of Exeter, SAMS is currently undertaking a government-commissioned review of the potential for marine mega fauna entanglement risk from renewable marine energy developments. This includes assessing the risks of marine mammals, basking sharks and marine turtles suffering injury or death due to entanglement within moorings and interconnector cables. The results of this review (available in 2014) should enable an objective assessment of the potential significance of this impact.

3.4. Entrapment
Primarily Wave Energy Converters

The potential for entrapment between moving parts depends on the device design. Those most likely to represent an entrapment risk are those with large moving parts and/or orifices. This is a risk that needs to be assessed on a project specific basis based on the particular characteristics of a device alongside a consideration of species-specific behaviour in the specific site and there is probably little potential for generic research to inform this issue. Likewise the opportunity to haul-out on devices will be device specific. There have been no reported incidents of marine mammal injury as a result of entrapment at any wave device deployment, although it is important to note that the monitoring required to rule out interactions has not been in place.

3.5. Noise
Wave and Tidal

Noise from construction activities (e.g. drilling to install structures on the seabed) and noise from operation of devices have been identified as potential impacts.

Lepper and Robinson (2013) carried out a detailed review of the current knowledge of underwater noise emissions from the construction and operation of wave and tidal devices. This report made a number of conclusions based on data reported in assessments to date, particularly that:

- *The radiated noise during the construction and operation phase of existing wave and tidal projects is not at a level likely to cause injury to the hearing of marine mammals, even at close range; and*
- *Radiated noise during operation and construction of both wave and tidal developments is unlikely to cause significant behavioural effects at long ranges[2] from the development site (to date the environments where construction has taken place have required drilling rather than piling, construction noise may be a bigger issue should piling be required).*

Lepper and Robinson (2013) also identified knowledge gaps, the most critical issues being the relative importance of background noise to device noise in animals' ability to detect and respond to devices (and therefore avoid collision). The degree of noise related disturbance from operational devices will be very device specific and will depend on the configuration of moving parts/presence of gear boxes, etc. Noise related displacement effects are likely to be of most issue in small arrays in narrow passageways or to the extent that displacement occurs over large areas as a result of large arrays. However empirical data on the extent of behavioural responses to devices will be necessary to parameterise these impacts and enable predictions for larger scale arrays.

3.6. Displacement/habitat exclusion
Wave and Tidal

Individual devices have a relatively small physical footprint so it is unlikely that the presence of single devices and small arrays will pose a significant risk of displacement and habitat exclusion at a level likely to result in significant impacts, unless sited in areas that are particularly critical for marine mammals. However, even a small degree of avoidance of smaller arrays in constrained passages or larger arrays in open water will lead to displacement and potential barrier effects. There is a limited evidence base to suggest whether marine mammals will avoid or be attracted to devices and arrays and any responses are likely to be device, location and species specific. Data from surveys at SeaGen at Strangford Lough demonstrated small scale local avoidance of the turbine by harbour seals (up to a few hundred metres). Further analysis of the EMEC wildlife monitoring data may further inform this question when the outputs are available in 2015.

> **"Individual devices have a relatively small physical footprint so it is unlikely that the presence of single devices and small arrays will pose a significant risk of displacement and habitat exclusion at a level likely to result in significant impacts"**

Robinson and Lepper (2013) suggest that noise from devices studied to date will not have a behavioural effect at 'significant'[3] ranges and that the noise from tidal and wave devices are rarely as high as those quoted for a 'modest' vessel (and often an order of magnitude less). However the main uncertainty is related to how any potential effect will scale up when more devices are installed in commercial scale arrays. Data collected from deployments of single devices and small arrays will be vital in predicting how significant an issue this might be in future. Modelling approaches can then utilise the data from early deployments and response studies to understand the implications of scaling up (Carter, 2013). Although model predictions should be validated by monitoring as arrays are developed.

There have only been a small number of examples of monitoring potential displacement of marine mammals at operational wave and tidal devices. These include monitoring at EMEC (Robbins, 2011a, 2011b) and at SeaGen in Strangford Lough, Northern Ireland (Keenan et al., 2011). The wildlife monitoring data at EMEC is currently under analysis and this study will report in spring 2015. Monitoring of seals and harbour porpoises in Strangford Lough has shown a temporary reduction in porpoise activity in the Lough and narrows during construction, which subsequently returned to baseline levels. Complete barrier effects were not shown for either harbour seal Phoca vitulina or harbour porpoises Phocoena phocoena; both species continued to transit through Strangford Narrows past the turbine. However, harbour seals were found to exhibit small scale avoidance (within a few hundred metres) during SeaGen operation. The extent of avoidance observed was less than that predicted based on the sound field surrounding the turbine and other observations of seal responses to noise and is likely to reduce the potential for collisions. Seals also moved through the channel less often (~20% less) at times when the turbine was operating relative to when it was not (Keenan et al., 2011; Lonergan et al. in prep).

The consequences of any displacement or habitat exclusion depends very much on an animal's functional use of an area and it is important to note that traditional monitoring metrics such as abundance or density in a given area, may be poor predictors of the importance of an area. Therefore, research should be focused on understanding how, where, why and when marine mammals use the specific environment to understand the likely consequences of disturbance or exclusion. It is unlikely that developer driven, site specific monitoring will be able to address these issues and therefore strategic monitoring efforts need to be accelerated to understand this for key species in priority areas.

3.7. Ecological effects
Wave and Tidal

Tidal and wave developments may cause ecological changes which will impact on marine mammals. These include 'artificial reef' effects, structures acting as fish aggregating devices ('FADs'), or changes to tidal flow and patterns of sedimentation which affect the benthos or the presence of pelagic prey species. Although precautionary assessments of the potential for these impacts are required as part of the EIA process, these often rely on subjective 'expert judgement'. There is insufficient knowledge to currently predict these impacts with any certainty.

3.8. Linking individual effects and behavioural responses to population level consequences
Wave and Tidal

If the baseline population dynamics of a species are well understood, and the magnitude and distribution of effects of a wave and tidal device on individuals can be estimated, then computer simulation may be able to estimate likely long-term population consequences for a development. The recent development of PCOD models or a subset of PCOD referred to as Population Consequences of Acoustic Disturbance ('PCAD') dealing specifically with acoustic disturbance effects is an example of an attempt to achieve this. An example of a recent project developing such a framework which will be used to predict impacts of renewable energy developments is the 'Interim PCOD Framework' currently being developed by SMRU Marine in collaboration with regulators, Statutory Nature Conservation Bodies ('SNCB') and other stakeholders. Harwood & King (2012) describe the critical sets of information required for the development of Interim and Full PCOD frameworks and includes consideration of impacts from wave and tidal developments. The framework may need a level of refinement to be useful for wave and tidal developments.

The use of the PBR as a level of 'acceptable' mortality is another approach which is used to place individual level effects (mortality) in the context of the sustainability of the population. A review of the currently available approaches and tools for linking individual effects to population consequences may be useful to regulators and advisers tasked with making decisions on individual project consents as well as understanding the potential for cumulative impacts from a number of developments.

[1] http://scotland.gov.uk/Topics/marine/Licensing/SealLicensing/PBR

[2] A definition of 'long ranges' was not provided by the authors of this review.

[3] What constitutes a significant range was not defined by the authors of this review.

4 Impact Mitigation

Measures that may reduce potential impacts on marine mammals are currently being developed; with much of this work being driven by advances in design aimed at maximising the economic potential of wave and tidal devices and minimising environmental impact. For example, the Optimising Array Form for Energy Extraction and Environmental Benefit ('EBAO') project funded by NERC is working on incorporating environmental considerations into optimal array design procedures. Similarly, alterations in device design may reduce potential impacts such as threat of entrapment or the acoustic output of an operating device.

Near field monitoring around deployments is a priority to determine whether further development of mitigation for specific impacts is necessary. For example, if collision does turn out to be a serious concern for tidal developments, mitigation solutions will need to be developed and implemented rapidly. For example, the current mitigation adopted at SeaGen involves operators monitoring active sonar around the clock to trigger shut-down in the presence of suspected marine mammals. This is not commercially viable as a general approach and alternative solutions will need to be developed if a need for them is demonstrated. These may take a variety of forms: real-time automatic detection systems linked to shutdown, or the use of deterrents linked to detection systems or continuous deterrent systems. However these solutions will need a significant degree of development, validation and refinement before they can be confidently adopted on commercial developments (Wilson and Carter, 2013). Given this, there is currently a certain degree of technical risk as it is uncertain how effectively any of these approaches will perform.

It will also be important to integrate monitoring and mitigation systems into the design of devices in the future (in terms of integrating power and communications). This will enable the requirements to be integrated into devices at the design stage and reduce the need for inefficient 'retro-fitting' of monitoring equipment after fabrication and deployment, or the need for development of stand-alone solutions to operate independently in harsh environments.

“The use of the PBR as a level of ‘acceptable’ mortality is another approach which is used to place individual level effects (mortality) in the context of the sustainability of the population”

5 Key Research

TABLE 2. KEY MARINE MAMMAL RESEARCH

PROJECT TITLE/PUBLICATION	BRIEF DESCRIPTION	REPORTING
RESPONSE (NERC MREKE)	This project aims to understand how marine wildlife (marine mammals, birds and large fish) respond to different marine environments and to marine renewable devices. This project will provide valuable information on species behaviour that will inform the understanding of risks to marine mammals (notably collision and acoustic disturbance) enabling better assessments and array layout planning. https://ke.services.nerc.ac.uk/Marine/Members/Documents/NERC-DEFRA%20research%20project%20summaries/RESPONSE.pdf	This project is due to report in 2014
FLOWBEC PROJECT (NERC MREKE)	This project is primarily aimed at understanding how the physical behaviour of the marine environment influences the behaviour of marine wildlife and to understand the responses of marine wildlife to marine renewable devices. http://noc.ac.uk/project/flowbec	This project is due to report in 2014
OPTIMISING ARRAY FORM FOR ENERGY EXTRACTION AND ENVIRONMENTAL BENEFIT ('EBAO') (NERC MARINE RENEWABLE INITIATIVE)	This project will establish and evaluate a design feedback process, which allowing energy extraction to be maximised while minimising environmental impact. Engineers will work with developers to establish development scenarios which will then be modelled to assess levels of ecological impact. This modelling will establish the sensitivity of impacts to changes in array and device design. https://ke.services.nerc.ac.uk/Marine/Members/Lists/Projects/DispForm.aspx?ID=2	This project is due to report in 2013
IMPACT ASSESSMENT TOOL (AQUATERA)	This tool enables users to determine the potential effects associated with a project that could be significant and screen out those that will not be. The database is updatable and will be populated with further information as it becomes available.	The IMPACT Assessment tool is available at http://www.marine-impact.co.uk/index.asp
WILDLIFE OBSERVATION PROGRAMME (EMEC)	EMEC are embarking on an analysis of long-term datasets that have been collected across their wave and tidal energy sites over the previous eight years. The aim of the analyses is to provide insights in to a range of issues including displacement of marine mammals. Key to this will be an assessment of the power of the monitoring data to detect changes.	The project is due to report in spring 2015.
MONITORING REPORT SYNTHESIS (EMEC)	A large number of monitoring reports of tidal energy devices have been produced by individual developers based at EMEC. However, these are not usually publically available and can lack authority being often based on a single device. EMEC is planning to undertake a review of these reports and provide a synthesis of these monitoring reports to highlight common themes.	This project aims to start in the second half of 2013 (reporting date to be confirmed).
WELSH GOVERNMENT MARINE RENEWABLE ENERGY STRATEGIC FRAMEWORK STUDIES	Desktop review of collision risk of marine mammals from underwater devices Studies of marine mammals in Welsh high tidal environments – tracking studies of grey seal pups in tidal areas and acoustic and visual monitoring for harbour porpoise in tidal areas. This project also included the development and testing of vertical hydrophone arrays for determining cetacean use of the water column.	Reported in 2011 Reports can be downloaded here http://mresf.rpsgroup.com/FileBrowser.aspx

TABLE 2. KEY MARINE MAMMAL RESEARCH

PROJECT TITLE/PUBLICATION	BRIEF DESCRIPTION	REPORTING
MARINE MAMMAL SCIENTIFIC SUPPORT RESEARCH PROGRAMME AT THE SEA MAMMAL RESEARCH UNIT (SMRU; MARINE SCOTLAND FUNDED). RESEARCH IS FOCUSED ON GENERAL MARINE MAMMAL PROJECTS BUT SOME WILL FOCUS ON RENEWABLES RELATED RESEARCH.	To recalibrate existing data on abundance and distribution of marine mammals in user-friendly format for industry and regulators.	Seal maps available http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes/usage/SDMreport
	An assessment and review of existing collision risk models. Recommendations on the data required to parameterise collision risk models.	Due to report in 2014
	Reviewing the utility of the Joint Cetacean Protocol ('JCP') to assess whether the tools being developed under the JCP analysis can be developed to address concerns at the scale of marine renewable development.	Due to report in 2013
	Monitoring harbour porpoise behaviour in tidal rapids using drifting array hydrophone systems.	Due to report in 2013
	Research into the unexplained seal deaths ("corkscrew" seals).	Due to report in 2013
MAPPING DISTRIBUTION AND ACTIVITY OF UK SEALS (SMRU; MARINE SCOTLAND AND DECC FUNDED)	1. to generate usage maps distinguishing between foraging and travelling; 2. to investigate changes in activity budgets resulting from at-sea developments; and 3. to identify core foraging areas.	Due to report in 2013
HAUL OUT CONNECTIVITY OF GREY AND HARBOUR SEALS (MARINE SCOTLAND AND SNH FUNDED)	The network of movements between haul out sites will be mapped using grey and harbour seal telemetry data.	Due to report in 2014
COLLISION DAMAGE ASSESSMENT (SMRU; SNH FUNDED)	A series of collision damage assessment trials with carcasses of seals and/or other species when available using a purpose built test rig.	Due to report in 2014
ESTIMATION OF HARBOUR PORPOISE ABUNDANCE FROM TPOD/CPOD CLICK DETECTIONS (CENTRE FOR RESEARCH INTO ECOLOGICAL AND ENVIRONMENTAL MODELLING (CREEM); MARINE SCOTLAND FUNDED)	Convert TPOD/CPOD output (click-positive minutes) to an index of actual harbour porpoise density.	Due to report in 2014
THE USE OF ACOUSTIC DEVICES TO WARN MARINE MAMMALS OF TIDAL-STREAM ENERGY RENEWABLE DEVICES (SCOTTISH ASSOCIATION FOR MARINE SCIENCE (SAMS); MARINE SCOTLAND FUNDED)	This project will investigate whether existing marine mammal acoustic deterrent devices (ADDs) could be used to mitigate collision risks in Scottish waters. To do this firstly measurements of ambient sound in Scottish seas will be undertaken. They will then be used as an input together with source level of existing acoustic deterrent devices (pingers, ADDs etc) to the acoustic warning model developed by SAMS to assess their effectiveness.	Reported September 2013
DETERMINING THE FACTORS AFFECTING UK GREY AND HARBOUR SEAL HABITAT PREFERENCE. (SMRU; MARINE SCOTLAND AND DECC FUNDED)	Using grey and harbour seal telemetry data, habitat preference will be modelled using information on environmental and physical characteristics in order to understand the features of the environment that are important for marine mammal habitat preference. This will enable prediction of the potential for impact where data on seal density may not be available.	Due to report in 2014

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PROJECT TITLE/PUBLICATION	BRIEF DESCRIPTION	REPORTING
HEBRIDEAN MARINE ENERGY FUTURES – PROJECT 2 – SITE SURVEYS AND PROJECT 4 – MONITORING INTERACTIONS AND GATHERING DATA FOR CONSENTING ACTIVITIES.	Projects focused on identifying and characterising wave energy sites off the cost of the Outer Hebrides. Projects so far have developed methodology for acoustic monitoring of cetaceans around wave energy converters. http://www.hebmarine.com/web/Home.html	Project completes April 2014
SAMS/EXETER UNIVERSITY ENTANGLEMENT REVIEW	Government-commissioned review of the potential for marine megafauna entanglement risk from renewable marine energy developments. This includes assessing the risks of marine mammals, basking sharks and marine turtles suffering injury or death due to entanglement within moorings, interconnector cables etc.	Due to report in 2014
SAMS PHD STUDY	Using hydrodynamic modelling, studies of carcass buoyancy and validation telemetry, this studentship will determine the likely beaches where turbine-struck large vertebrates would eventually strand.	TBC
QUEENS UNIVERSITY BELFAST	Hydrodynamic modelling to predict where marine mammal carcasses would end up if collisions occur.	TBC
MARINE CURRENT TURBINES: STRANGFORD LOUGH EMP	Monitoring of marine mammals programme covering baseline, installation and operation phase of 1.2 MW tidal turbine in Strangford Lough, Northern Ireland.	Final report http://www.marineturbines.com/sites/default/files/SeaGen-Environmental-Monitoring-Programme-Final-Report.pdf Several peer reviewed publications forthcoming in 2014.
MARINE CURRENT TURBINES: COLLISION STRIKE MODELLING	Modelling the consequences of a turbine blade strike on marine mammals based on OpenHydro Killer Whale strike analysis	2014

6 Recommendations

Our understanding of the potential impacts on marine mammals of wave and tidal devices is developing, yet a large degree of uncertainty still surrounds the potential impacts of many devices, demonstration and commercial scale arrays. The focus of stakeholders should therefore be on the rapid consenting and monitoring around small arrays (or larger arrays developed in phases). Research priorities identified over the next three to five year period include:

- *Collecting data at and around deployed devices and arrays to reduce uncertainty around predicted impacts, with the priority impacts being:*
  - *a. Collision risk with tidal devices; and*
  - *b. Displacement resulting from both wave and tidal devices (where achievable taking into consideration scale of site, location, natural variability in abundance and distribution of marine mammals).*
- *Further development of sensor arrays and methodologies to carry out this data collection;*
- *Research into the consequences of collisions between marine mammals and tidal devices for individuals, for example, what is the relationship between rotor speed and tissue damage?*
- *Development of models allowing predictions of the population level consequences of individual responses (potential to develop Interim PCOD framework currently being progressed for the impacts of offshore wind). This could include a review of the currently available approaches and tools for linking individual effects to population consequences and how these are used in consenting decision making;*
- *Understanding marine mammal use of high energy environments to enable predictions of how these may change following the deployment of wave and tidal generators;*
- *Research into mitigation of identified (and potential) impacts;*
- *Development and update of sensitivity mapping for key species (i.e. characterising areas of high importance) and the incorporation of this information into marine spatial planning; and*
- *The development of research results into tools that can be used by developers (and regulators) to provide robust assessments.*

It is likely that only the first of these objectives can be met though work carried out specifically at individual sites. There needs to be a discussion about how much of this should form part of the requirements for individual developers through licencing conditions and how much should be progressed more strategically given the wider benefit of these data to the industry as a whole. The remaining objectives are considered more appropriate for strategically led studies with industry input and contribution to funding where appropriate in a co-ordinated approach.

> **“Our understanding of the potential impacts on marine mammals of wave and tidal devices is developing, yet a large degree of uncertainty still surrounds the potential impacts of many devices, demonstration and commercial scale arrays”**

> It is hoped that the recommendations presented here can form a starting point for the development of specific projects that will be funded through this initiative...

The proposed Wave and Tidal Joint Industry Project led by The Crown Estate is one example of a strategic initiative to identify key consenting-related research priorities and progress potential research projects. It is hoped that the recommendations presented here can form a starting point for the development of specific projects that will be funded through this initiative.

In addition, this review has identified a number of more general recommendations to aid the development of the marine renewable energy industry (many of these are common across all taxa and are not specific to marine mammals):

- *Encourage dialogue that makes a distinction between wave energy and tidal energy schemes and ensures the differences in impacts are understood;*
- *Strategic scientifically robust and timetabled monitoring of test devices and arrays (through pre-construction, construction and operation phases) should follow survey protocols designed to ensure a high degree of statistical power and outputs should be made publically available, regardless of whether these are developer or strategically led;*
- *A regularly updated synthesis of available monitoring reports should be co-ordinated centrally; and*
- *Focus survey programmes for projects in development, as far as possible, on answering specific and relevant questions or understanding the behaviour of key species in relation to key risks as opposed to a general recording of sightings.*

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