ASSESSING THE RISKS TO MARINE MAMMAL POPULATIONS FROM RENEWABLE ENERGY DEVICES – AN INTERIM APPROACH

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1. Preamble

1.1 Purpose

The Joint Nature Conservation Committee, the Countryside Council for Wales and NERC Knowledge Exchange Programme commissioned a workshop to develop discussions on the risks from renewable energy devices to marine mammal populations (see Appendix I for the agenda and Appendix II for the list of participants). The Statutory Nature Conservation Bodies (SNCBs) have identified a need for a framework to enable the assessment of risk of impacts on marine mammal populations arising from disturbance and mortality caused by the installation and operation of marine renewables (offshore wind, wave and tidal). Up to the present date, consenting decisions involving considerations of impact to marine mammals have been made based on the premise that small scale individual wind farms or demonstration wave and tidal projects will not carry a risk to the Favourable Conservation Status (FCS) of populations nor to the integrity of Natura 2000 sites. In some cases, the risks to marine mammal populations posed by tidal stream projects have been reduced to acceptable limits by defining collision thresholds.

The SNCBs have advised the regulators that the evidence in this field is very limited and that it is becoming increasingly difficult to advise on new developments without a transparent, logical, repeatable and biologically relevant framework for assessing likely impacts and (if needed) managing the risk of impacts to marine mammal populations. Current advice to regulators and developers is based on limited evidence within a context of potential negative impacts on populations of marine mammals, particularly those that could arise from the cumulative effects of several large scale developments or multiple novel technologies combined with other ongoing pressures. The rapid expansion in the number and scale of offshore renewable developments combined with the precautionary principle required to assess likely impacts and the lack of a thorough understanding of the actual effects is resulting in consenting challenges that reinforce the need for an assessment framework. These challenges are likely to be most significant for developments within the range of small, semi-resident populations and for multiple developments with the potential to impact cumulatively on marine mammal populations. As a consequence SNCB advice to industry and regulators is likely to be provided on a very precautionary basis.

To progress this issue, a workshop was hosted to consider and assess the challenges that stakeholders are currently facing when having to determine and manage the risks of renewable energy devices to marine mammal populations. The aim of this workshop was to explore the development of a UK based framework, appropriate for assessing mortality and disturbance impacts on marine mammal populations, arising from the installation and operation of offshore renewables. The workshop gathered academics, regulators, nature conservation advisory bodies and industry to agree on an approach that is appropriate to the issues and populations of concern. In particular, the aim of the workshop was to reach agreement on the questions that need answering and their regulatory context, to identify and discuss the available data and assumptions, to discuss and identify the most appropriate modelling approaches and to explore the scenarios and levels of impact to be considered.

1.2 Ongoing projects

The workshop received contributions from a range of participants regarding current work on risk assessment, and research efforts to inform those approaches. Sonia Mendes (JNCC) and Kate Smith (CCW) introduced the regulatory and nature conservation context for this issue (as explained above).

Phil Gilmour (Marine Scotland) presented Marine Scotland's policy framework to manage renewable risks for marine mammals. This five-part framework includes consultation processes to define a scientific programme to learn more about key species and using early construction opportunities to learn more about effects and responses to development. This first step provides a foundation to then refine and improve assessment techniques. It also provides information to develop a strategic monitoring network to ensure that baseline information is collected and ability to respond to impacts defined. Marine Scotland works with industry to investigate cost effective substructure alternatives to mitigate impacts. Finally, this process is reviewed by international experts. This framework focuses on working with others (including statutory advisors and industry) to establish partnerships between the public and private sectors.

Ben Leyshon (Scottish Natural Heritage) talked about the on-going work on the development of a framework that could be used to predict the population consequences of boat traffic disturbances (PCOD) for the Moray Firth bottlenose dolphin population. A poor understanding of the consequences of marine and coastal development on the dolphin interest of the Moray Firth Special Area of Conservation were perceived as causing delays in the processing of planning permissions, marine licences and Harbour Revision Orders. This prompted a consortium of development agencies, under the auspices of the Moray Firth Ports and Sites Strategy Working Group to initiate a study to look at the interactions between boats associated with these developments and the dolphins. The study comprised an analysis of the way in which boats and dolphins use the 3,500km2 that make up the Moray Firth SAC and predicted, through a range of scenarios, the consequences of this for the dolphins. The work has already yielded useful findings in that it has clearly shown that routine traffic associated with the offshore renewables fabrication facilities proposed for the area are unlikely to increase significantly the exposure of the dolphin population to boat traffic whereas a single tour boat located within a core area for the animals would result in a significant amount of extra time that they spend with marine vessels. This has valuable management implications as it allows regulators to focus on where the management of vessels will have the greatest benefit. The work has also shown the priority areas for future data collection and it has prepared the framework for a predictive model that would significantly improve our understanding of the population consequences of disturbance events in the Moray Firth. Funding for the study came from Scottish Natural Heritage, Highlands and

Islands Enterprise, The Highland Council and the Scottish Government and further funding to take forward the predictive model is currently being sought.

Paul Thompson (University of Aberdeen) presented a specific approach on current environmental assessments for proposed windfarm construction on Moray Firth harbour seals that have developed a framework to assess potential impacts at the population level. The framework was designed to provide an interim approach that could be used from Q4 2011, and subsequently be updated with new data or more complex modelling approaches. Predictions of spatial variation in received noise levels are integrated with modelled seal distributions, and estimates of the number of individuals displaced or suffering auditory injury are then made using the best available information on dose-response curves. Expert judgement defines linkages between these effects and changes in vital rates, and the long-term impacts of these changes are compared with baseline scenarios using a deterministic matrix model. The approach has been developed in discussion with academics, industry, regulators and the statutory nature conservation advisors. These discussions and initial applications have highlighted how sensitivity analysis can focus research priorities, and subsequently allow the framework to be updated with new data & exposure criteria. Key challenges have been identifying appropriate thresholds or dose-responses for PTS & displacement, and then linking those responses to changes in vital rates. Uncertainty in different components of the framework has been assessed qualitatively using IPCC guidelines. It is recognised that our precautionary approach within each component is likely to have led to a tendency to overestimate worst case scenarios. Current work aims to gather new data to reduce uncertainty and identify how best to develop most credible rather than worst case scenarios.

Ben Wilson (Scottish Association for Marine Sciences) presented ongoing work as part of the RESPONSE project. The goal of this project is to understand the mechanisms through which MRED operations might be influencing the habitat use and behaviour of marine mammals. The project focuses on estimating the risks of collision and habitat exclusion the installation of wave and tidal-stream energy devices might pose.

David Lusseau (University of Aberdeen) presented recent research and management developments pertaining to the population consequences of disturbances. He showed how inferring non-lethal effects of human activities (disturbances) on population growth rate can provide a transparent and defendable assessment process. We now understand, by synthesising a large number of studies, that human activities are perceived as risks by marine mammals and consequently animals integrated this risk factor in their perception of their environment when making behavioural decisions. This means though that we cannot expect a simple dose-response curve for behavioural disturbances because the level of disturbance will be context dependent. Individuals facing different ecological and life history constraints, and with different needs at the time of the disturbance, will react to it in different ways according to the best trade-off for them at the time. However, we can now link these behavioural mechanisms to demographic processes, thanks to recent statistical developments, by inferring the physiological constraints they place on individuals (Figure 1). Once we have indentified how disturbances can influence the vital rate of individuals, we can then assess how many individuals will be affected to 'unsafe levels' of disturbances and therefore estimate the impact of the disturbances on the FCS of the exposed population based on its altered growth rate. This mechanistic approach provides a way to predict potential impact of development and can therefore be integrated as part of an adaptive management scheme to advise on development proposals.

John Harwood (University of St Andrews) described the progress which has been made by a Working Group on the Population Consequences of Acoustic Disturbance (PCAD) that has been supported by the US Office of Naval Research. The Group has developed a simplified version of the PCAD framework developed by the US National Research Council's Committee on Characterizing Biologically Significant Marine Mammal Behavior in 2005 (see Figure 1), and has applied this framework to a number of case studies, including elephant seals, coastal bottlenose dolphins and North Atlantic right whales. Although detailed information of the kind that was used in these case studies is not available for any marine mammal population in the UK, they provide a clear indication of what information needs to be elicited from experts for these populations.

1.3 Framework

PCAD/PCOD

We currently regulate non-lethal interactions between human activities and wildlife populations using a descriptive approach. That is, we assess the impact the activity can have, try to infer the consequences of those impacts on populations, and advise on the levels of activity that can be deemed safe. However, this approach has serious shortcomings. Firstly, although legal frameworks to conserve wildlife populations set population trajectory targets, such as FCS, which are ultimately based on population growth rate, a specific target growth rate is seldom (if ever) specified in the definition of FCS. As a result, the biological relevance of the observed impact, the most crucial element of the decision-making process, is often the least well-informed. This leaves the assessment of the potential effects of a particularly activity open to multiple interpretations and challenges. Secondly, the current reactive approach reduces our ability to generalise from one assessment to the next. We are therefore often left with piecemeal case studies from which it is difficult to draw general conclusions that can provide sound scientific foundations to management decisions.

The impact of traditional activities that have a lethal effect on wildlife populations, such as hunts or by-catch, can be interpreted in terms of traditional harvesting population models. But a paradigm shift is required if non-lethal interactions between wildlife and human activities are to be managed effectively. To achieve this, we need to invest in a new approach to scientific advice on the management of natural resources that focuses on developing predictive power. Such a change is needed because non-lethal interaction is quickly overtaking traditional exploitation as the most important feature in the landscape of many species (Lusseau et al 2011). This is particularly important for the management of cetacean populations, which are increasingly exposed to a wide variety of industries that can affect their behaviour in ways that have potential population-level consequences.

The recently developed PCAD/PCOD framework (Figure 1) can provide a sound basis for this new approach because both the direct (acute, e.g. mortality) effects and the indirect (chronic) effects of disturbance from a potential development on vital rates can be incorporated in the same modelling framework. This allows potential cumulative impacts to be evaluated. In addition the translation of behavioural responses into effects on vital rates allows non-lethal effects to be converted into "takes" (estimates of the number of animals that may potentially die as a result of a particular development). These takes can then be incorporated into a management framework like that used to calculate Potential Biological Removals (see below), which are directly related to conservation targets. A framework based on a combination of PCOD and PBR can take full consideration of all cumulative impacts, and the additional uncertainty associated with translating behavioural response to effects on vital rates.

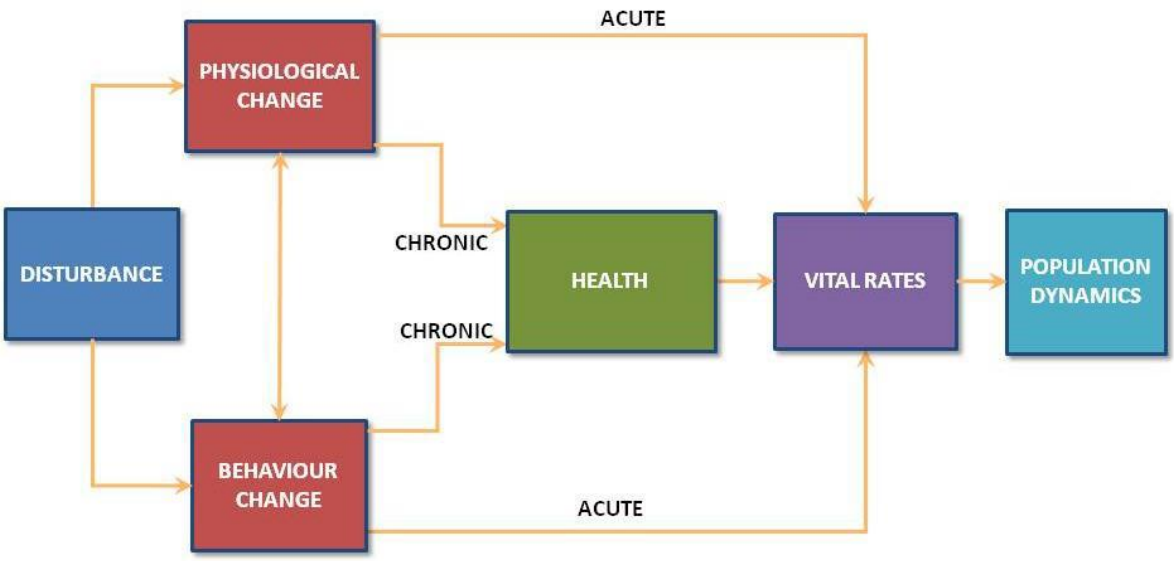

Figure 1. *The PCOD framework for modelling the population consequences of disturbance developed by the ONR working group on PCAD (Anon. 2012). The term "Health" is used to describe all aspects of the internal state of an individual that might affect its fitness. These include, for example, the extent of its lipid reserves and its resistance to disease. "Vital rates" refers to all the components of individual fitness (probability of survival and producing offspring, growth rate, and offspring survival).*

The PCOD/PBR approach would provide developers with a clear indication of how much disturbance (development) a population can sustain by estimating the level of "takes" that would be caused by a development scenario and contrasting it with the permitted level of takes to maintain the favourable conservation status of the population(s) affected. This would allow developers to use the best available evidence at the time to determine whether or not their long-term developments are likely to be permitted. It will also direct further research and monitoring to reduce uncertainty and improve the predictive power of the mathematical models that underpin the process.

Potential Biological Removal (PBR)

The estimated risk of a development needs to be provided in a format that relates to the conservation targets of the legal frameworks in place to manage marine mammal populations. For EU populations this framework is based on the concept of FCS. Potential Biological Removal (PBR) provides a way to calculate the potential effects of "takes" on conservation targets that accounts for known uncertainties. PBR can thus be used as a tool to assist in the determination of acceptable mortality thresholds for losses from populations.

PBR is one of several management procedures available for determining appropriate limits for marine mammal bycatch (e.g. Cook et al. 2012). It was developed by the US National Marine Fisheries Service in response to the US Marine Mammal Protection Act. PBR provides a trigger value that, if exceeded, results in a Take Reduction Team being convened to identify ways to reduce the number of anthropogenic marine mammal mortalities to a level below the calculated PBR. It has a long history of application in the US, where it has undergone considerable scientific scrutiny and evaluation, and is relatively easy to use. It has recently been adopted in the UK for setting limits on the number of seals that can be taken under licence to protect fisheries interests.

In its original form, the PBR level represents the maximum number of animals, not including natural mortalities, which may be removed from a marine mammal population whilst allowing that population to reach or maintain its Optimum Sustainable Population (OSP). However, **we use the term here to describe any algorithm that can be used to determine how the "take" (direct or indirect) of a certain number of individuals will affect conservation priorities for the affected population, and that takes account of uncertainties about the population's status.** Hence the PBR procedures would be extended to account for effects on all vital rates to assess whether any activity would lead to a change in the conservation status of the population(s) affected.

1.4 Interim approach

Given that some developers have already submitted proposals for which consent decisions need to be made by regulators within agreed timescales, there is a need for an interim approach to provide guidance until more complex modelling frameworks are available. Such an interim approach will need to rely on semi-quantitative, expert judgements that feed into the proposed risk assessment framework. Whilst this interim approach will provide a major improvement on the current situation, there will still be a high level of uncertainty associated with the outputs and it is essential that a more quantitative modelling framework is implemented in the medium to longer term.

2. Management scheme

2.1 Survey-deploy-monitor

The workshop reached a **consensus** on an interim approach that would fit within the context of the survey-deploy-monitor strategy. This will allow management advice to be provided at an early stage, whilst the longer term quantitative modelling framework is being developed and implemented. This interim approach needs to be repeatable and objective, it should incorporate the best available evidence at the time, it should be transparent about the way judgements are made, and it should generate a defensible audit trail. Such an approach can also be used to identify the key parameters that require more evidence and data, hence help prioritise research and post-consent monitoring. It will reduce planning risks and therefore reduce some of the financial uncertainty associated with the current rounds of consent applications for renewables.

2.2 Adaptive management

The survey-deploy-monitor approach should be used in an adaptive way, so that advice is always based on the best available, and most up to date, evidence at the time. Expert judgement will be used to infer values for those model parameters that cannot be estimated from currently available data. A carefully planned period for the management cycle needs to be defined prior to its instigation to present a clear timeframe after which both management advice and the management process will be reviewed and updated.

Some participants raised **concerns** that an adaptive management scheme might deter investors, because uncertainties about the future of a development(s) would increase the risks involved. However, it was **agreed** that discovering that there was a significant impact once the development had started and with no management plan in place could have even greater costs. Furthermore, risks for investors can be reduced if adaptive management measures are clearly defined at the outset.

Participants also raised the **issue** of how cumulative impacts might be managed under such a scheme. For example, restrictions have been imposed on the allowable mortality that current tidal developments might cause to cetacean populations because these populations are already exposed to fisheries bycatch. The allowable mortality for these developments has been calculated using a PBR approach that takes account of the uncertainty surrounding the estimates of the number of animals that are killed accidentally by fisheries every year. Developers are faced with a situation in which their activities might, on their own, have only small impact on a population, yet this level of impact could potentially be sufficient to tip this population in an unfavourable conservation status because of existing impacts from other human activities. These conundrums exist in the context of a wide range of societal issues, and their resolution must be guided by political debate. Once advisors and regulators receive clear guidance on the way impacts should be prioritised (e.g. via interpretation of the Renewables Directive by the relevant decision makers), then the total annual human-induced mortality that can be sustained by a particular marine mammal management unit could be partitioned between different industries. Again it was **noted** that an adaptive management scheme would be the most appropriate method to respond to such public concerns.

2.3 Uncertainty

There were considerable **discussions** on how to deal with uncertainty in the modelling approach and how to assign levels of confidence to its outputs. While there is value in quantifying uncertainty for each step of the process, simply accumulating these uncertainties over all the steps will probably not provide a realistic estimate of the level of uncertainty associated with the predicted final outcome. A better approach for comparing scenario outcomes would therefore be to assign a single overall estimate of uncertainty for each scenario, whilst also keeping an audit trail of the uncertainty for each step in the risk calculation to guide research priorities and monitoring.

Participants at the workshop **agreed** that it was necessary to consider not only the worst case scenario, in accordance with the precautionary approach, but also the most credible scenario, to allow comparison between scenario outcomes and to ensure that outcomes were realistic, pragmatic, and not unnecessarily precautionary.

Participants supported the use of the following scale developed by the Intergovernmental Panel on Climate Change (IPCC, 2005) for evaluating and communicating the uncertainty and confidence associated with expert judgement as to the correctness of a model, analysis or statement:

Terminology	**Degree of confidence in being correct**
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

2.4 Eliciting expert judgement

Where data are lacking or where uncertainties are particularly high, expert judgement will be used to infer parameter values in the modelling framework. Expert judgement will therefore play a crucial role in the interim approach.

Some participants were **sceptical** of the use of expert judgement to inform model parameters and uncertainties, because they felt that there will never be a sufficient agreement between experts to provide grounds for a consensus. However, techniques that **do not require consensus building**, such as the Delphi method (Martin et al. 2012), have been developed for eliciting expert judgement. Furthermore, expert consensus is not essential for implementing the PCOD models, because alternative models could be run using contrasting parameter estimates that reflected the range of expert opinions (Martin et al. 2012; Garthwaite et al. 2005).

Expert judgement has been widely used in conservation biology and management (Martin et al. 2012) to provide information about model parameters and help characterize uncertainty. These judgments are then confronted and replaced with empirical estimates, as they become available. However, expert judgments, without additional empirical evidence can form the basis for decisions when these are urgently required.

Expert judgement is often used during the assessment of evidence during the environmental impact assessment process. As the evidence (often limited) is taken forward through to consenting, a further layer of expert judgement is then applied to assess the significance of the predicted impacts and making decisions on the acceptability of the environmental risk. However, expert judgement has so far been used in a rather *ad hoc* way. The lack of standards in how to elicit expert judgement and the lack of an agreed approach for dealing with uncertainty can cause problems for all stakeholders during the consenting process. It is therefore important that a clear and transparent procedure is used to elicit expert judgement in order to improve the trust between industry, regulators and advisors.

This procedure should specify the format of elicitation (e.g. through an online survey, interviews, independent vs. group), which types of experts should be called upon, how experts will be trained, the questions to pose, methods of analyses of responses, etc (Martin et al. 2012). In addition, it is important to find ways to quantify uncertainty and minimise bias in the elicited information (O'Hagan et al. 2006).

3. Population Consequences Of Disturbances (PCOD)

3.1 Advantages/disadvantages

There was an overall **agreement** amongst workshop participants that the PCOD framework was a suitable method to use for the assessment of lethal and non-lethal disturbance and that there are few alternative options available. One of the greatest advantages is that PCOD can incorporate both lethal (acute) and non-lethal (chronic) effects of disturbance into a single framework. Further, a PCOD approach allows non-lethal effects to be represented as “takes” which can then be used in a PBR-type calculation that takes account of the conservation targets in place for each species. Estimates of the lethal effects that are due to collision or entanglement with marine renewables devices can be also be treated as takes and incorporated directly into PBR-type calculations. In addition, there is scope to incorporate in PCOD behaviourally-mediated injuries if/when the behavioural mechanisms causing these acute consequences are understood.

The PCOD approach makes it possible to identify the most important sources of uncertainty and the key sensitivities, enabling regulators to be clear about the level of confidence associated with the overall assessment. The same information can also be used to guide research and monitoring.

There were **concerns** from some participants that the PCOD approach might be over-precautionary if uncertainties from every step in the risk assessment are accumulated. However, as noted in section 2, this problem could be addressed by assigning overall estimates of uncertainty to worst-case and most-credible versions of each scenario, thus allowing scenarios to be compared on a consistent basis.

3.2 Research gaps

Some participants expressed **frustration** over the fact that, although there had been many lengthy discussions about the needs for research, there had been little or no action to inform these gaps and several opportunities might have been lost during for example the first rounds of offshore windfarm deployment. One of the benefits of the PCOD framework is that it can be used to quantify the extent to which different research actions will reduce the uncertainty and sensitivity associated with the risk outcomes in a transparent and objective way. These uncertainties may not only be related to the species of interest, but also its prey species and other oceanographic factors. It was suggested that the outcomes of previous discussions organised by the US Office of Naval Research (Anon. 2012) could be used to identify gaps of knowledge and to avoid duplicating work effort.

3.3 Uncertainty

While most participants **agreed** that it is good to have a unified and consistent framework to deal with uncertainties, some raised **concern** that too great an emphasis on uncertainty could lead to a development being stopped altogether. Another big risk for developers is that identifying all sources of uncertainty will make it easier for groups that are ideologically opposed to a particular project to assemble their case. These issues can be partially addressed by using a PBR-type approach, because this can explicitly account for all sources of uncertainty in calculating the potential impacts of a development on FCS and so a management and monitoring plan can be put in place if necessary to deal with those uncertainties. In addition, given the increasing raised awareness of the issues and uncertainties related to renewables development, there doesn't seem to be a reasonable alternative to dealing with those uncertainties.

There were considerable **discussion** about the definition of management units and boundaries for marine mammal populations. These are required to place the number of animals that might be impacted by a development into the context of population sizes, trends and ranges. There were particular **concern** about how FCS could be determined for wide ranging species, such as harbour porpoise and minke whales, for which management units are very hard to define. The definition of management units is crucial if the outputs from a PCOD model are to be used in a PBR-type calculation, which is the final step of the risk assessment model.

It was **agreed** that the definition of management units is urgently required, and that it is vital that the same definitions are used in all areas of concern. To define management units, it was **suggested** to set up a one day workshop of experts to discuss and reach consensus at a UK level on management units for the five species that are considered to be of greatest concern: grey seal, harbour seal, harbour porpoise, bottlenose dolphin, and minke whale. JNCC mentioned the possibility of using an upcoming meeting of the Interagency Marine Mammal Working Group (SNCBs group with 3 external scientific advisors) on harbour porpoise management units. . The remit of this meeting could be extended to assign management areas for the other cetacean species that are of particular concern. The definition of management units should be based not only on what is most biologically meaningful, but also what would be most meaningful for management. As for the other components of the management scheme, the definition of management units will be an adaptive process: when more evidence becomes available these units can be updated for following applications.

4. Potential scenarios

4.1 Functional groups vs. key species

There was considerable **discussion** about whether or not species should be classified into "functional behavioural response" groups according to their life history strategies and characteristics. Most participants seemed to **agree** that such a classification would, in the long term, be a sensible and logical approach, since it would make the framework more flexible and easier to extend to other species and areas. However, dividing the five species of main concern into functional groups as part of the interim approach, would not simplify this task. It was therefore **agreed**, that it would be best to consider each of these species as representatives of a different functional group, which could help classification of new species in the future.

The life history strategies and characteristics of species can still be used to assess the resilience of the populations of concern to disturbance. Where information on the species of interest is lacking it may be possible to draw inferences from better-studied species with similar life histories that are exposed to similar ecological conditions. The key factors that will influence the effect of disturbance on vital rates are:

- **reproductive strategy** – where a species lies on the spectrum from pure capital breeders (rely exclusively on stored fat reserves to support reproduction and lactation) to pure income breeders (rely entirely on foraging during lactation). Income breeders will be more sensitive to disturbance during the breeding period than capital breeders.
- **body size –** will influence how long an animal can survive without feeding. For example, a short term disturbance will affect a harbour porpoise more immediately and with possible worse consequences than a baleen whale which can survive long periods without food.
- **predation risk** - species whose distribution is constrained by the risk of predation will have fewer options in the way they respond to disturbance
- **population status** - if a population is close to carrying capacity, disturbance that results in the displacement of individuals will cause increased competition, and therefore reduced per capita energy intake, in the area into which they move
- **degree of diet specialisation** - highly specialised species whose distribution is constrained by the availability of preferred prey are likely to be more susceptible to the effects of disturbance in areas of critical habitat.

Factors that will determine the effect of changes in vital rates on a species Favourable Conservation Status include:

- **overall population growth rate -** populations with a high potential growth rate will be more resilient to the effects of short-term disturbance
- **vital rates affected by disturbance -** the population consequences of disturbance depend on the sensitivity of the population growth rate to changes in the vital rates that are affected by disturbance. For example, most seal populations are more sensitive to a small change in adult survival than to equivalent changes in pup survival or pregnancy rate.

Other aspects influencing the magnitude of impact of behavioural responses on vital rates are:

- **environmental constraints –** such as range, temporal and spatial distribution of the population's resources. Patchy resources will offer fewer opportunities for population to compensate for lost opportunities due to disturbances.

- **predation risk –** increased predation risk caused by change in habitat use due to displacement.
- **diet specialisation** – more specialised species may not be able to cope with changes in fish assemblages caused by installations.

4.2 Test scenarios

Impact studies on marine mammals are few or lacking altogether for some types of developments. This makes it important to develop test scenarios to develop PCOD. However, there seemed to be uncertainty among workshop participants regarding how much testing is needed, and what parameters to consider.

The developers **pointed out** that the Crown Estate Underwater Noise group is trying to identify what needs to be done with relation to monitoring and research on potential effects arising from the disturbance associated with construction, where it can be done and by whom. That group wants to focus funding on a few thoroughly undertaken projects rather than spreading efforts without obtaining relevant results. Intensive monitoring of baseline conditions, and during and after construction should be used to understand impacts. The regulator might also need to consider some sort of controlled exposure experiments to inform the mechanistic links in PCoD models, although many in the group believed this would not be feasible given the legislative regime regarding the protection of marine mammals. It was also recognised that there were likely to be problems scaling up results from single/small deployments to understand the potential impacts of larger ones.

There was also a suggestion to hold a regulators and industry meeting to build scenarios describing plans for renewable energy construction and deployment. These would identify the possible scenarios that could impact marine mammal populations. The meeting would also be intended to give developers an idea of when the effects of their developments might cross the threshold for population level effects. It was **suggested** that the Crown Estate's Underwater Noise group should be involved in this.

5. Interim approach

Two possible interim approaches were **discussed** during the workshop. One relied on a vulnerability-impact matrix (Figure 2) which could then partitioned, using expert judgement, into safe, risky, dangerous and unsafe areas. Expert opinion could then be used to score the risk for each marine mammal management unit using a qualitative descriptor of its vulnerability, based on the species' life history strategy and ecology (e.g., prey availability) and a quantitative assessment of the impacts (such as displacement caused by noise) it might experience under a particular development scenario.

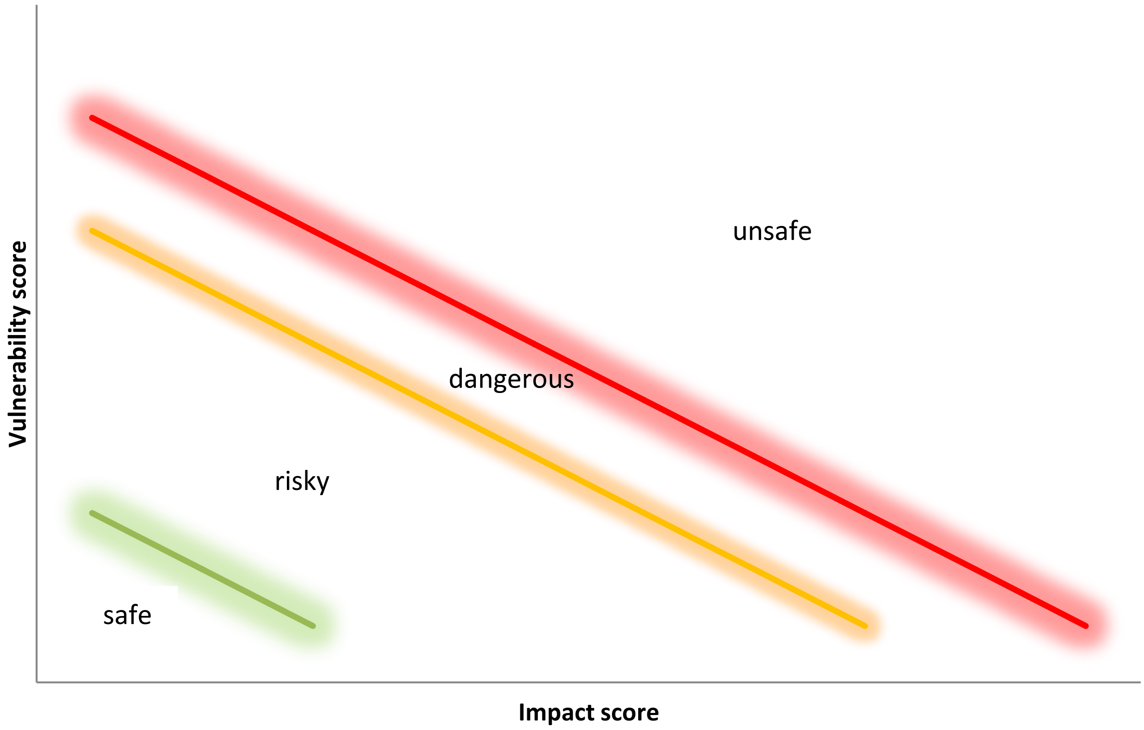

Figure 2. A vulnerability-impact matrix within which scenarios for individual marine mammals management units can be categorised.

During **discussion**, it was **highlighted** that expertly defined thresholds, with associated uncertainties, might be treated as targets rather than guidelines. In addition, there were many potential ways in which the effects of the different disturbances that might impact animals could be combined into a single impact score, and this could lead to issues of interpretation.

A second approach would be to implement PCOD models using expert judgement to define the missing parameters and uncertainties. As previously noted, this approach would allow assessment of both lethal (acute) and non-lethal (chronic) effects of disturbance, and its outputs could be used in a PBR-type calculation so that they were directly related to conservation targets.

The PCOD approach is well suited to an adaptive management scheme because the same modelling approach can be used in each cycle of the scheme. Under such a scheme, expert judgement provided as part of the interim approach would be progressively replaced by values estimated using empirical data from monitoring programmes, thus increasing the precision and accuracy of model outputs.

Another advantage of PCOD is that it takes account of uncertainties, and can be used to determine the sensitivities of model outputs to these uncertainties. This can be used to guide research and monitoring at an early stage of a development, thus increasing the predictive power of the interim PCOD model in a positive feedback cycle.

6. Generic guidance to assess the risk of marine renewable energy development to a marine mammal management unit

Here we present some guidance on how PCOD might be used in an interim manner. PCOD can be used to guide a transparent narrative of the risk assessment associated with a new development. This interim approach may be required in a number of cases where development proposals may be reaching maturity before the expert judgement PCOD implementation can be completed.

There are five key questions that need to be addressed and for each of these an assessment of the associated uncertainties.

Are my activities likely to kill or disturb marine mammals?

If individuals are likely to be killed, assessors need to define the mechanisms from which the lethal takes might emerge in order to qualify its risk (rare v highly likely) and how many individuals are likely to be affected. The sustainability of this take needs to be determined using for example PBR.

What will be the effect of the proposed activities on individuals?

If activities will disturb individuals then we need to know the behavioural mechanisms through which the proposed activities will have these effects. Once those are identified then we need to assess the ways these behavioural disruptions might influence the condition of individuals. To do so, we need to focus on distinguishing the behavioural domains affected (e.g., foraging, vigilance, movement, socialising, resting) and whether they are likely to affect energy expenditure or energy acquisition. Here we need to some discussion about the size of the effects on these domains, how uncertainty about this and how sensitive the effect is to our uncertainty assessment. For example, increased movement will results in increased energetic expenditure yet the certainty with which we need to know this effect is not a priority because cost of transport is not onerous for marine mammals. Hence, a 10% increase in movement or a 30% increase in movement may have similar consequences. Conversely, a 10% disruption in foraging opportunities would be a very different effect from a 30% disruption in foraging opportunities and hence the consequences of this effect are much more sensitive to its associated uncertainty.

What will be the consequences of these impacts?

We can use information about the species life history tactics (capital v income breeder) and the ecological constraints the population faces (e.g., predation risk and the patchiness of prey resources) to assess which vital rate may be affected by those energetic constraints. For example, females have to balance maintaining their own survival and both the rate at which they can produce offspring and the investment they make in these offspring (offspring survival). Here again, we need to assess how sensitive these vital rates are to the estimated energetic constraints placed on individuals by the disturbances. To do so, we need to assess the potential size of the effect of energetic impacts on vital rates. If such effects cannot be determined we can alternatively assess a range of effects and continue in the assessment with these multiple scenarios.

How many individuals will be exposed to unsafe levels of impacts in the proposed activities?

Firstly, the exposed management unit (MU) needs to be defined and its current trajectory assessed (stable, declining, increasing). This trend provides a first test of the potential sensitivity of a population to any additional human interactions as a MU in an unfavourable conservation status may not be able to compensate for additional stressors. The MU trajectory is also important as it can have indirect effects on the PCOD. For example, if the MU is at carrying capacity then individuals displaced by disturbances will compete with others.

Once the MU is defined, we need to assess how many individuals will be exposed to the activities and, of those exposed, how many will be exposed to disturbance intensity that will trigger the impact consequences described above. We can also incorporate uncertainty here by carrying out several assessments for a number of exposure scenarios.

Other factors influencing the propensity that disturbances will affect FCS

The spatial ecology of the MU can interact with disturbances to have compounding impacts. For example, if the species has specific habitat or diet requirements then it will be more sensitive to displacement and may not be able to compensate as well as other species for being excluding from these key areas. In contrast, it may also mean that it will be more reluctant to move away from critical habitats and therefore be exposed to other impacts (e.g., TTS or PTS). Displacement can also lead individuals to be less (or more) exposed to other human activities. So, it may be possible for example that a development proposal will lead to reduced risk of by-catch because animals are excluded from an area where by-catch prevails.

What is the likely risk for FCS of the exposed management unit?

Assessors have to determine the sensitivity of the MU's FCS to the demographic consequences of the impacts. They can use knowledge about the life history strategies and tactics of the exposed species to do so. For example, the population growth rate of long-lived, slow reproducing species is most sensitive to the survival probability of adult females. However, large effects on yearling and juvenile survival probability can also affect FCS. They can then account for the proportion of the population that is likely to have its vital rates affected and conclude what will be the impact on the MU trajectory. Uncertainties surrounding both the estimate of the proportion of individuals exposed to unsafe levels of activities and the likely consequences of the impacts will drive conclusions about the sensitivity of the FCS to the proposed activities and the likely risk to the FCS.

7. Proposed management scheme

A consensus approach **emerged** from **discussions** at the workshop. The PCOD approach can be used with appropriate outputs from the environmental impact assessment to provide a transparent and auditable trail on how overall risk is estimated. There is a need for UK coordination of impact assessments given the transboundary nature of species and their populations, the issues and the developers that are involved (see appendix 1). Such coordination would allow regulators and developers to have a better informed strategic perspective of the ecological risks that would be incurred at different stages of a development. This would decrease planning risks. As an interim approach, the information to feed into the PCOD framework could be obtained by eliciting expert opinion. This opinion can be progressively replaced by observational and experimental data to improve risk assessment and decrease uncertainties. Monitoring would help with the assessment of the potential impacts of future developments by reducing uncertainty and filling evidence gaps. Hence, an adaptive scheme, in which information available as well as management processes can be reviewed, is desirable to improve conditions required for risk assessment. A proposed management scheme for coordinating this process is outlined in Appendix III.

8. Research plan

8. 1 Research plan developed by workshop participants

During, and immediately after, the workshop, participants developed a research plan to implement the Population Consequences of Disturbance (PCOD) model for each of the five key marine mammal species of concern regarding renewable energy developments in UK waters (grey seal, harbour seal, harbour porpoise, bottlenose dolphin, and minke whale). These models will include both chronic and acute risks associated with disturbances, including the integration of collision risk models for wet renewable devices and the effects of Permanent Threshold Shift (PTS) on the vital rates of individuals (e.g. survival and probability of reproducing successfully).

The research plan was revised after the workshop in the light of Defra's announcement that it was on course to establish a new Habitats and Wild Birds Directives Marine Evidence Group in July 2012, and further discussions with Marine Scotland, NERC, JNCC and CCW. The Defra Evidence Group will bring together Government, its agencies, The Crown Estate, industry, environmental organisations and academia. One of the priorities of this Group is "to address the priority research gaps where improved understanding of existing evidence, or filling gaps in research, would help to reduce undue precaution in decision making." Areas identified in the Review include: modelling of effects on populations of marine mammals and validating critical input parameters, e.g. population framework, displacement risk, and developing a more strategic approach to post construction monitoring of marine developments. The Defra review will almost certainly address a number of the work streams identified in the initial research plan. In addition, Marine Scotland has already asked the Sea Mammal Research Unit (SMRU) to provide advice on appropriate biological population units to be used in assessments of the potential impacts on cetaceans of marine renewable energy developments in Scottish waters (work stream 3). Section 8.2 outlines a revised research plan that takes account of these developments.

There are seven work streams to the initial research plan:

1. **Develop a procedure to elicit expert judgement,** i.e. a structured way in which expert judgement will be elicited and integrated to inform linkages in the PCOD models. The aim is to make this process highly transferrable to other situations (different types of developments and different species) in which expert opinion are needed to make managerial decisions based on impact assessment.

2. **Hold a regulators and industry meeting** (regulators and their advisors, Crown Estate and industry representatives) **to identify scenarios** to be considered for the first iteration of PCOD model implementation. This will focus on developing a national overview of proposed developments and identify possible project specific scenarios as well as population/management unit-wide cumulative scenarios to be evaluated using PCOD models.

3. **Define management units for the five key species**. There are ongoing efforts by the Statutory Nature Conservation Bodies to define the boundaries of management units for

marine mammal species in UK waters. Those agreed management units will be used in the PCOD implementation.

4. **Develop an interim approach** for assessing the risk of potential population level consequences of any current and forthcoming renewables proposals in the very short term (3-6 months). This will use a risk matrix approach to categorize the risk posed to each relevant marine mammal management unit by a particular renewables proposal, in terms of the vulnerability of the unit and the potential impact of the development. It will be based on a combination of the Potential Biological Removal process currently used to assess the impact of licensed seal killing in the UK, and the approach developed for assessing the potential impacts of wind farm developments on harbour seals in the Inner Moray Firth. However, it will also provide a foundation for the full PCOD models described below as it will provide an indication of risk to populations and the uncertainty associated with that risk. This will allow the regulators to place the information provided in environmental impact assessments into a population/management unit level context and provide some guidance to developers on the parameters they need to consider in their assessments and the level of complexity and detail proportional to the perceived risk.

5. **Elicit expert judgement to inform the parameters and linkages in the five PCOD models** (work stream 1), such as life history strategies and characteristics, and environmental constraints. Expert opinion will also be used to help refine the definition of Favourable Conservation Status of each species, taking account of other efforts that are currently underway to quantify this concept (e.g., by the World Conservation Union (IUCN), the International Whaling Commission, and ICES).

6. **Implement the five PCOD models** using information obtained through expert elicitation to evaluate the scenarios developed in the regulators/industry meeting (work stream 2). This modelling will focus on two scales of potential impact:

    a. A project-specific perspective to assess the potential population consequences of disturbances and potential collisions associated with specific projects

    b. A strategic perspective to evaluate the cumulative impacts of disturbances associated with all planned and existing developments to which each species management unit is exposed.

    A key priority will be to assess the sensitivity of the assessment to uncertainty at each step in risk calculation. This sensitivity analysis will be used to guide research priorities and monitoring schemes.

7. **Further development and quantification of PCOD.** In the longer term, values obtained through expert opinion should be progressively replaced by observational or experimental data. Data acquisition, prioritised using the sensitivity analyses previously described, will emerge from survey and monitoring programmes associated with development plans.

Additional dedicated research projects may be necessary if key data cannot be obtained from planned development projects.

Proposed timeline for research plan (Financial year 2012-2013)

Tasks	Q1	Q2	Q3	Q4	Cost
1. Develop a procedure for eliciting expert judgement	→	→			£10K
2. Scenario development	→				
3. Define management units for 5 key species	→				
4. Develop pre-interim approach based on risk matrix	→				£50K
6a. Develop underlying PCOD models	→	→			£100K
6b. Elicit expert opinion for PCOD models		→	→		£10K
6c. PCOD sensitivity analysis			→	→	£30K
6d. PCOD implementation using expert opinions			→	→	£100K

8. 2 Revised research plan

This revised research plan takes account of the developments since the initial workshop described in section in 8.1. In addition to providing an interim approach that can be applied over the next 3-6 months, it will also provide value input to the Defra Evidence Group when it begins its work.

1. Define management units for key species. As noted in section 8.1, Marine Scotland has asked SMRU to provide advice on appropriate biological population units to be used in assessments of the potential impacts on bottlenose dolphins, harbour porpoise, minke whales, Risso's dolphins, white-beaked dolphins, common dolphins, white-sided dolphins and killer whales of marine renewable energy developments in Scottish waters. This advice is due to be provided before the end of May and will inform the work of an interagency group established by the SNCBs to define management units for marine mammals. These units will form the basis for the following work streams.

2. Carry out an analysis of the sensitivity of the key marine mammal species to marine renewables

Furness & Wade (2012 Vulnerability of Scottish Seabirds to Offshore Wind Turbines. Report prepared for Marine Scotland by MacArthur Green Ltd. pp40) recently reviewed the risks to Scottish seabirds from offshore marine turbines. They built on the results of an analysis by Desholm (2009. Avian sensitivity to mortality: Prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90: 2672-2679) which identified population size and population ‘elasticity’ as two of the most important criteria determining the impact of marine turbines on these populations. A similar analysis for the key marine mammal species, building on the output from work stream 1 (above) and the Phase 3 analysis of data on cetacean abundance and distribution in UK waters collected under the Joint Cetacean Protocol (JCP), would provide a strong foundation for the interim PCOD approach described in work stream3 (below). In addition, it would provide valuable input to the next round of Scoping Studies for marine renewables. The analysis would provide the following information:

- For each species, identify which vital rates are most likely to be affected by marine renewables developments.
- Identify what empirical information is currently available to estimate the relationship between the proposed scale of a marine renewables development and its potential effect on these vital rates, and what information would need to be obtained through expert elicitation.
- Determine the potential sensitivity of each of the management units identified in workstream 2 to changes in these vital rates by applying stochastic population modelling to information on the size and status of these units derived from the Phase 3 JCP analysis and seal population data provided by SMRU.
- Provide a generalised version of this stochastic population modelling framework for use in work stream 3.

3. Develop and implement an interim PCoD approach

This interim approach takes account of the fact that the basic biological information required to develop the full PCoD model shown in Figure 1 for the key marine mammal species is unlikely to be available in the near future. However, it may be possible to obtain this information in future using the results of carefully designed monitoring programmes associated with the construction and operation of renewables developments. Instead, the interim approach will use the simplified version of the PCoD framework shown in Figure 2, in which most of the information linking behavioural and physiological changes to their effects on vital rates and population dynamics is obtained using expert elicitation. This approach will build on work that has already been carried out to predict the potential effects of renewables developments on harbour seal and bottlenose dolphin populations in the Moray Firth, and the advice that the SNCBs are currently providing to developers to help them complete Habitat Regulations Assessments for seals and bottlenose dolphins.

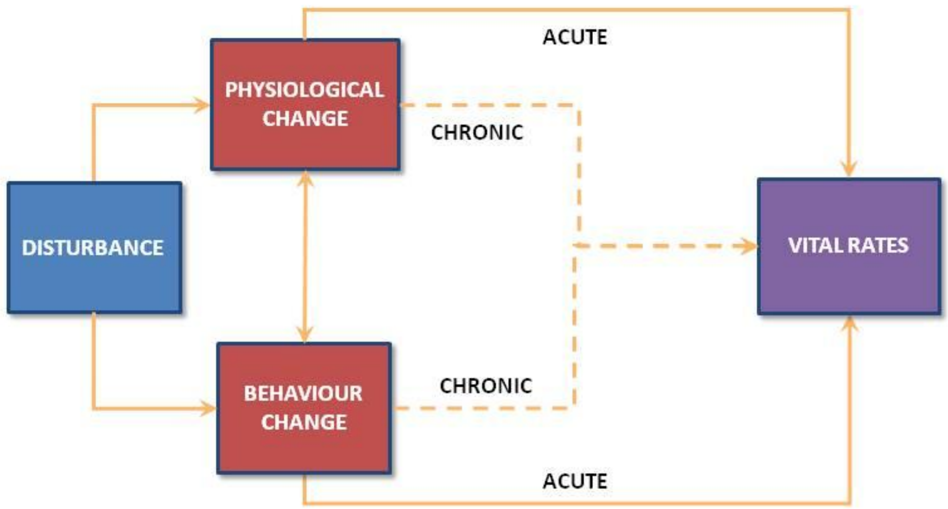

Figure 2. *A simplified version of the PCOD framework shown in Figure 1 that can be used as part of an interim approach. The 'transfer functions' that define the chronic effects of physiological change and behavioural change on vital rates are shown with dotted lines to indicate that the form of these functions will usually be determined using expert elicitation rather than empirical evidence. The term 'vital rates' refers to all the components of individual fitness (probability of survival and producing offspring, growth rate, and offspring survival).*

This interim approach will be able to take advantage of the fact that the Office of Naval Research's working group on the Population Consequences of Acoustic Disturbance, which developed the PCoD framework shown in Figure 1, will be considering the use of expert elicitation at its next meeting on 10-12 July. A number of world authorities on expert elicitation will be attending this meeting, and their advise can be used to inform the activities carried out as part of this work stream. The work stream will have the following components:

- Draw up a list of question that will form the basis for the expert elicitation process, in consultation with the SNCBs and regulators
- Agree a list of experts who will be consulted as part of the expert elicitation with the SNCBs and regulators
- Conduct expert elicitation and synthesise results, taking full account of uncertainties identified in the elicitation process

- Use the results of the expert elicitation process, in the combination with the stochastic population modelling framework developed in work stream 2, to evaluate the potential effects associated with renewable energy developments (death or injury, temporary hearing loss, behavioural disturbance) on the conservation status of each marine mammal management unit.

4. Investigate whether use of the PBR formula is an appropriate way of preventing significant long term effects at the population level

As noted in section 1.3, Potential Biological Removal (PBR) provides a way to calculate the potential effects of "takes" on conservation targets that accounts for known uncertainties. PBR can thus be used as a tool to assist in the determination of acceptable mortality thresholds for losses from populations. It was developed by the US National Marine Fisheries Service in response to the US Marine Mammal Protection Act. However, this does not mean that simple application of the PBR formula in UK situations will result in compliance with the Habitats Directive. The consequences of applying this formula, or some variant, for the conservation status of a population can be evaluated using a stochastic population modelling framework, such as that would be developed as part of work stream 2. This was the approach adopted by Wade (1998 Calculating limits to the allowable human-caused morality of cetaceans and pinnipeds. Marine Mammal Science 14: 1-37) during the development of the PBR formula, and by SMRU in evaluating its use for managing takes of seals. A similar approach could be used to evaluate the effectiveness of the PBR formula for regulating the "takes" of other marine mammal species that might be associated with marine renewables developments, and to determine whether less precautionary approaches might be equally effective.

Proposed timeline for revised research plan (Financial year 2012-2013, ie Q1=April-June 2012)

Tasks	Q1	Q2	Q3	Q4	Approx. Cost
1. SNCB interagency group defines relevant management units					
2. Sensitivity analysis					£10K
3. Develop interim PCoD approach based on expert elicitation					£50K
4. Investigate feasibility of simple PBR metric for assessing "takes" associated with marine renewables					

Acknowledgements

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Appendix I

Agenda

10:00 -10:30: arrival and coffee

10:30- : TALKS TO PROMOTE DISCUSSIONS

10:30-10:45: Introduction and Regulatory framework (Sonia Mendes)
10:45-11:00: Marine Scotland
11:00-11:15: The challenges of management implementations, the Moray Firth experience (Ben Leyshon, SNH)
11:15-11:30: Seals and windfarms – current ways to inform development (Paul M. Thompson, UoA)
11:30-11:45: RESPONSE (Ben Wilson, SAMS)
11:45-12:00: Science to manage sub-lethal effects as takes (David Lusseau, UoA)
12:00-12:15 Modelling long-term and cumulative impacts of disturbances (John Harwood, UoA)

12:15-13:00: WORKING LUNCH

13:00-16:00 BREAK-AWAY GROUP DISCUSSIONS

Coffee provided at 15:00. The group will be moderated to ensure that all key points are covered in discussions (see below)

1. The benefits and disadvantages of managing non-lethal effects as takes
2. Develop test impact scenarios (wind, wave, and tidal)
3. Define the main points that a management scheme for these issues should cover
4. Proposal for an interim approach to assessing the significance of effects of renewables on marine mammal populations

16:00-16:30 PLENARY SESSION – SYNTHESIS AND CONCLUSIONS

- Summary of highlighted challenges
- Ways forward

Appendix II

List of participants

Sonia Mendes (JNCC)

Kate Smith (CCW)

Annie Linley (NERC)

David Lusseau (U Aberdeen)

John Harwood (U St Andrews CREEM)

Paul Thompson (U Aberdeen)

Gordon Hastie (SMRU Ltd)

Ben Wilson (SAMS)

Ian Boyd (U St Andrews SMRU)

Fredrik Christiansen (U Aberdeen)

Enrico Pirotta (U Aberdeen)

Ben Leyshon (SNH)

Phil Gilmour (Marine Scotland)

Nathan Edmonds (CEFAS)

Catarina Rei (EDPR)

Nancy McLean (NPC/EDPR)

Claire Bowers (MMO)

Claire Ludgate (Natural England)

Ruth Barber (MMO)

Bronagh Byrne (SSE Renewables)

Ruth de Silva (NPC/REPSOL)

Fiona Manson (SNH)

John Baxter (SNH)

Sophie Thomas (DECC)

Zoë Crutchfield (Mainstream RP)

Ian Davies (Marine Scotland Science)

Lucy Greenhill (JNCC)

Andrew Finlay (Crown Estate)

Julie Cook (DECC)

Narumon Withers Harvey (DEFRA)

John Hartley (HAC)

Andrew Hill (CCW)

Tamsin Brown (Welsh Government)

Joseph Kidd (Marine Turbines)

Appendix III

Proposed Marine Mammal Renewable Advisory Committee (MMRAC)

Sonia Mendes, JNCC
Kate Smith, CCW

It was **discussed** and **proposed** to establish an Advisory Committee with the role to oversee the management of risk to marine mammals from marine renewable energy developments. This committee would be created to reduce the consenting risks associated with marine mammals and construction noise in light of the pressing need to develop renewable energy facilities to meet energy demand in the UK and the targets set by the Renewables Directive, and also of the requirements of the Habitats Directive to maintain or restore the conservation status of key marine species that include marine mammals;

This Committee would ensure national coordination in order to:

- better account for cumulative effects of multiple developments occurring in the range of marine mammal populations/management units,
- foster the ability to develop a strategic perspective for both regulators and developers,
- enable the coordination of research funding,
- further integrate the development of marine renewable energy sites in current marine planning efforts;

The *Marine Mammal Renewable Advisory Committee* (MMRAC) would provide advice on noise and mammals and direct different streams of work, including the implementation of PCOD. The group would have broad representation from regulators and their advisors, industry, and experts in the field.

The PCOD framework would be implemented by a separate working group comprised of scientists, experts in the field. This work would be undertaken in two stages, an interim and a longer term development. The interim stage would identify several renewable projects where concerns are very low and provide the much needed judgement and audit trail. It would also identify projects of most concern and where the uncertainty is greater, hence pre-empt risk and drive research/monitoring. The longer term development of the framework would allow a reduction of uncertainty and more objectiveness.

The PCOD implementation group would provide advice to the MMRAC on the risks associated with renewables accounting for both lethal and non-lethal impacts (Figure I.1).

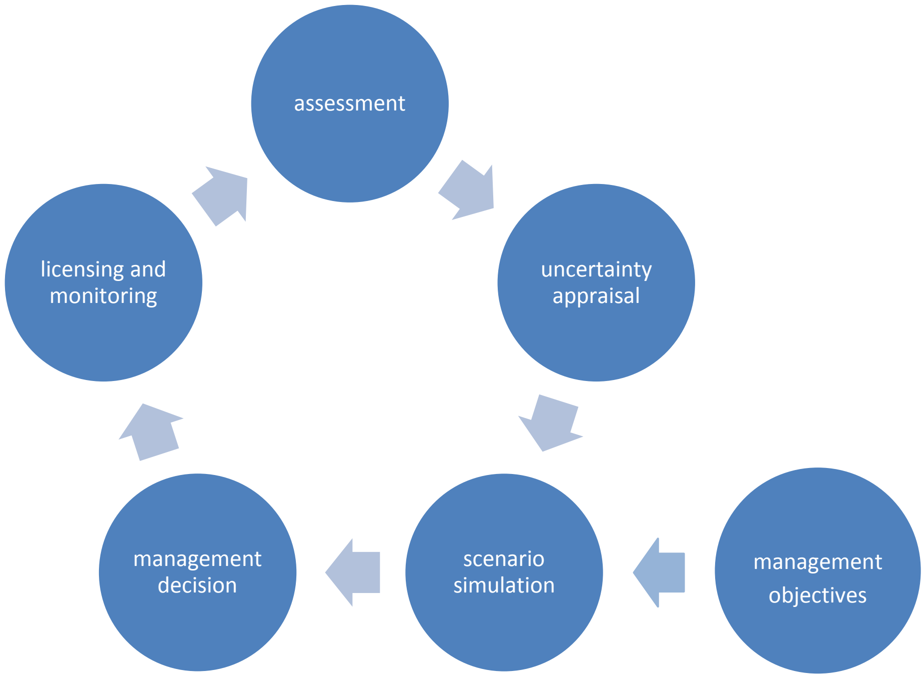

Figure I.1. MMRAC adaptive management cycle

In addition to the PCOD implementation group, a panel of independent experts from within and outside the UK would be contacted for expert judgement on parameters in the PCOD framework to allow the implementation group to finalise conclusions on the level of risk and uncertainty of population level impacts. The elicitation of expert judgement would be carried out in a structured, transparent process that ideally would be developed by an external independent contract and would be applicable to other areas such as seabirds (see Martin et al 2012).