Biological Effects of Marine Noise
Bristol - Feb 2012

A Workshop supported by the Strategic Ocean Funding Initiative (SOFI), the Natural Environment Research Council's Marine Renewable Energy Knowledge Exchange Programme (NERC), and the Underwater Sound Forum (USF).

Day 1 Discussion Groups

Chronic/Accumulative Effects – Andy Radford

ISSUES	SOLUTIONS
Timeframe?	Longterm existing monitoring systems – utilise these (POGO/IQOE)
Multiscale monitoring not necessarily occurring	? develop capacity for longer monitoring on data tags
Large movement of study animals	Small + medium + large scale approaches in parallel
Need population measures	
How to monitor health in individuals?	More inclusive indicators of 'health'
No standardisation of methods / responses / measures	IMO standards
No centralisation of archival data	POGO/IQOE - centralisation
Need for good experimental design (especially since many others factors)	Sampling across gradients (time series)

To date, the majority of experimental research examining the potential impact of anthropogenic noise on marine organisms has focused on acute exposures, for understandable logistical reasons. However, chronic exposure to noise, and resulting accumulative effects, represents a more realistic scenario for most organisms and noise sources.

Crucial to an improvement in this regard would be multiscale monitoring, potentially utilizing existing longterm acoustic monitoring programmes in combination with the development of data tags with extended lifetimes. To be successful, there needs to be some standardization of methods and response measures considered, to allow comparisons both within and between species.

If studies are to be conducted on free-ranging animals, which provides the most ecologically relevant data, careful planning is needed to include all periods for those species that engage in large-scale movement patterns. Individual health, as well as behavioural changes, needs to be considered and this will require careful determination of relevant indicators.

Ultimately, population level measures are required, and this is likely to entail integration of small, medium and scale-approaches run in parallel, along with good experimental design to control for the many other factors at play in natural conditions.

Sound Exposure Experiments – Vincent Janik

ISSUES	SOLUTIONS
Individual variation in reactions	Repeated measures design
Role of context	Control for context if possible
Lab / field comparisons	Needs further study
Sampling units and dependency issues	
Population differences	More studies on this
Sample sizes	Coordination of studies
Publication bias	Cannot be resolved easily
The use of pilot studies for management decisions	?
Selection of study species	Coordination of science groups

Sound exposure experiments are an important part of our approach to studying the effects of noise on marine organisms. Most of these studies have focussed on marine mammals because their hearing thresholds are much more sensitive than those of other marine animals. Given the difficulties of studying marine mammals in the wild, published efforts suffer from small sample sizes. This affects the conclusions that can be drawn. Several issues arise from small sample sizes. Individual variation and the social or motivational context in which the animal found itself when presented with a stimulus can have a dominant effect and blur effects of the experimental stimulus. One answer to this has been a repeated measures design. However, this is not always easy to implement in the field. Incomplete repeated measures lead to statistical problems when sample sizes are small. Additionally, experiments carried out at one site may not predict the behaviour in other populations of the same species. One solution to this problem is to try to coordinate different research groups so that data from separate efforts can be pooled. This also requires agreeing on the most relevant species or best model system to use. While experiments with some animals may be better than none from a scientific point of view, results from studies with small sample sizes or from captive studies are often used for management decisions in the field. This is problematic and may lead to inappropriate measures taken to mitigate the effects of noise. We also have to ask ourselves whether there is a publication bias towards studies that find an effect of noise. To counter such a bias, researchers have started to focus on dose-response curves to provide thresholds for noise effects. However, data are still too sparse to provide convincing dose-response functions.

Ocean Acidification and Anthropogenic Noise – Steve Simpson and Phil Williamson

ISSUES	SOLUTIONS
Food chain – primary production	Carbon capture test systems
	Temperature
Sound propagation?	
	Plankton blooms
Coral reefs + OA	Natural anologues
Decrease quality – decrease noise	Natural anomalies – Ischia, Baha, PNG
Increase received levels	Lab based approaches
- anthropogenic noise	
- detecting predators	Long-term datasets
- communication	
Ocean Acidification in Arctic Ocean	Sound propagation models of natural anomalies and measurements
Synergistic effects	
	Propagation of sound in shallow water
External pH / internal pH	
Boric acid – high frequency problem?	Adaptation, tolerance, evolution
Sensory responses	Global hydrophone networks e.g. CTBT (Comprehensive Test Ban Treaty)
Physiology / bone + exoskeleton growth	seasonal variation in chemical and pile driving noise
	Fish physiology – CEFAS and Swansea increase ocean acidification

In our discussion we considered the interactive effects of OA and AN from several perspectives. Potential interactive effects included:

- Influence of water chemistry on sound propagation, based on modelling studies suggesting sound will propagate further in OA conditions due to changes in concentrations of boric acid (which normally reduces sound propagation over long distances through absorption). The prediction made is that shipping noise will travel further forming a greater component of the ocean acoustic budget. In turn, this would impact on the ability of animals to detect predators/prey, reduce communication distances, etc. We were unsure whether the boric acid element of absorption was really more of a high-frequency issue.

- Effects of OA on habitat quality (e.g. coral reefs) with associated loss in the noise-producing component of the community. This would have knock-on effects for animals that use natural soundscapes for orientation. Reduced levels of natural noise would subsequently increase the impact of AN through masking.

- Predictions are that OA will be especially intense in polar seas, and with the Arctic Ocean changing in its sea ice coverage, and becoming more amenable to shipping and oil exploration, AO/AN changes to this relatively pristine environment could be dramatic.

- There is evidence that fish growth, including otoliths (earbones), is affected by OA conditions, and also that auditory responses of fish to habitat cues are affected for fish reared in OA conditions.

We discussed the idea of making measurements of sound propagation in naturally high CO2 environments (e.g. Ischia, Baha California, Papua New Guinea), and developing models that can predict propagation in predicted future conditions.

We endorsed the development towards longitudinal studies that study the adaptation of animals to OA conditions and explore the natural variation and scope for adaptation through subsequent generations.

We wondered whether there are natural cycles in CO2 conditions in semi-enclosed (e.g. day/night in a loch) or open water (e.g. seasonal plankton blooms) environments, which would enable propagation studies to be conducted, or long-term data (e.g. CTBT) explored wrt seasonal CO2 cycles.

Application of Risk Assessment – Annie Linley and Steve Simpson

ISSUES	SOLUTIONS
Gaps in our knowledge for mapping risk	4. strategic data/collection research
Behavioural – dose-response is context dependent	3. holistic approach
Sound propagation models have problems - even ‘good’ quality data not fit-for-purpose (especially mammals)	2. capture uncertainty
Risk framework needs to capture cumulative / interactive effects	1. develop framework in terms of biological significance

There are clear gaps in existing knowledge that limit policy and planning decision-making. There are increasing numbers of studies highlighting that noise <u>can</u> affect behaviour, but responses are likely to be dose-dependent and much less is known about levels or durations of noise exposure that cause effects. Additionally, behavioural responses are context dependent (e.g. age, sex, hunger levels, reproductive state). More work is needed to capture the cumulative effects of exposure to chronic noise or interactive effects of noise in concert with other environmental stressors.

Solutions discussed by this working group included: more strategic and coordinated data collection and collaborative research to address key knowledge gaps; a more holistic approach to research; better attempts to capture uncertainty in models (especially sound propagation models); and a research framework that considers effects of noise that are of obvious biological significance.

Extrapolating from experiments to population models – John Harwood

ISSUES	SOLUTIONS
Poor correspondence between experiments and models	Finding studying species for which extrapolation is 'easy'
Experiments are on a short time scale (but interested in long-term)	Technology to capture acoustic life-time (long-term acoustic tags)
Spatial scale over which the species move	Better communication between experimenters and modellers
➔ Find a suitable temporal and spatial scale	Mesocosm experiments
Challenging life-histories	
Extrapolating results from controlled experiments	
Extrapolation to non-resource limited context	
What are the community / ecosystem consequences?	

The main issues that the group identified were that the temporal and spatial scale of most experiments was insufficient to allow any clear inference about the population and ecosystem consequences of the responses that were observed to sound exposure. These issues could be addressed to some extent by an appropriate choice of study species. Individuals of this species would have to be sufficiently small that experiments could be conducted within a mesocosm that mimicked at least some of the species' most important ecological interactions. However, they would also need to be sufficiently large that they could carry devices capable of recording their exposure to sound and key aspects of their behaviour over time periods that were biologically meaningful (ie weeks, rather than days). Significant technological developments would be required before experiments of this kind would be feasible.

Do signal to noise or absolute levels determine impact? - Ben Wilson & Paul Lepper

ISSUES	**SOLUTIONS**
Permanent Threshold Shift Absolute Behavioural SNR Humans more disturbed when it is quiet Reaction levels in regulations Response dependent on strength of sound as well as SNR Is strength of noise or SNR the issue, or both? Is signal masked? Novelty of stimulus Is noise perceived? What extent is an animal already stressed in a noisy environment?	Broadband noise playback experiment Review of SNR in behavioural studies Similarity of signal and noise characterisations (example piling very different) Report absolute Report SNR Need all 3 Monitor reaction experiment 1. same ratios change signal 2. change signal to noise 3. signal similarity / noise Characterise noise locally In air parallels Test effects of variability in noise floor

The issue:
When performing controlled exposure experiments, background noise levels may differ from the original setting the trial is attempting to replicate. While substantial efforts are often made to faithfully reproduce the original signal, a differing background noise level will alter the signal-to-noise ratio and therefore the prominence of the exposure itself. If animals respond to detecting a signal alone then variations in background noise (so long as the signal is detectable) may have little relevance. However, if animals respond to relative levels then the ratio is important. Thus a playback may have two different outcomes based on the background noise rather than the exposure itself. This leaves two differing possibilities for a controlled exposure, first, preserve the signal irrespective of background noise or, second, scale the exposure to maintain the original signal to noise ratio.

Potential solutions:
This problem was recognised by all attending the group and clearly has implications beyond just controlled exposure experiments. It is also likely that physiological issues such as PTS and TTS are less prone to this effect than behavioural ones. Potential ways forward include: (1) Seeking parallels from terrestrial, including human examples; (2) Paying attention to background noise as well as the signal and not just overall levels but also its frequency composition and any temporal structuring; (3) In lab settings, simulate the background noise as well as the signal being tested; (4) In the wild, consider performing playbacks at sites with similar background noise characteristics; (5) Where appropriate, also test the importance of absolute and relative signal to noise ratios on animal responses.

Trade-Offs: noise v. resources – Peter McGregor

ISSUES	SOLUTIONS
	Not just food
Interpreting co-occurence Have appropriate mechanism (evolved recently)	Integrated approach (Marine Spatial Planning) Identify bottlenecks
Several recent trade-offs	Indicator of accumulated exposure / stressor (octopus timescale = days)
Prey ‘hiding’ in noise	
Timescales longer than experiment (experimental interpretation)	Add in social effects (position in social group gives another trade-off)
Compensatability	Long-term experiments (life time summation) Acoustic dosimeter Independent measures of trade off of interest -> Large N
Individuality of response	Identify e.g. condition, sex
Shape of assessment function (non-linearity)	Life history strategies Risk averse / risk prone “Stressor” literature
Outside evolutionary response (scale and time)	More terrestrial and freshwater fish

Animals have evolved to trade-off conflicting costs and benefits; in the welfare literature this has been referred to as adaptive self-expenditure (Barnard & Hurst 1996). Can marine animals trade-off exposure to noise for resource benefits such as food, mates and refuges? Anthropogenic noise is recent phenomenon on an evolutionary timescale (especially for long-lived organisms); therefore adaptations may not have had time to evolve. Also, other concomitant anthropogenic effects (e.g. habitat loss, other forms of pollution, reduced population size) may reduce the capacity to trade-off. In view of these factors sophisticated trade-offs would seem unlikely (but an integrated approach to assessing factors, similar to marine spatial planning, may help to identify trade-offs).

A current issue is how the propensity of marine animals to trade-off could affect interpretations / predictions from observation & experiment. Part of a solution is to consider the possibilities of trade-offs when interpreting observations of co-occurrence of marine animals and anthropogenic noise. Similarly, experimental approaches need to recognize that the timescale of the experiment and the trade-off may be very different.

Related issues include the extent to which animals can compensate (e.g. acquire elsewhere resources foregone to avoid noise); the influence of social structure on trade-offs (likely more important to remain with group than follow optimum individual trade-off) and the shape of the assessment function used in trade-offs (more likely to resemble a step function than gradual change). Solutions include recognizing the absence of such information and therefore the value in collecting it as part of studies. Since trade-offs are ultimately driven by lifetime reproductive success, data from lifetime acoustic dosimeters (based on archive tags?) may be required to identify trade-offs.

Barnard, C.J. and Hurst, J.L. 1996. Welfare by design: the natural selection of welfare criteria. Animal Welfare 5, 405-33.

Particle motion vs sound pressure – Annie Linley and Steve Simpson

ISSUES	SOLUTIONS
Technology (equipment): measuring particle motion	Web-based forum to share info / insight
Should we be measuring one or the other or both?	Involving industry in technology trials
Standardization of methods	
Are we even measuring effects on hearing or is it something else?	Asking those who have data to make them available
Intercalibration	

This working group included several early career scientists grappling with the particle-pressure challenges presented in playback experiments. The equipment needed to measure pressure (hydrophone) and particle motion (accelerometer) were discussed, and the importance of ideally measuring both in experimental set ups was highlighted.

The major outcome of this working group is that this is not a new problem, rather one that researchers have faced for decades. The idea of an online forum for postgrads/postdocs to compare notes, equipment and discuss setups emerged from the discussions, and this is now an action being taken forward as an outcome of the workshop. It is hoped that industry-research links and partnerships will result from this forum and by sharing data and archiving discussions this will accelerate the progress made on this crucial experimental issue.

CLS/SDS
29.3.12

Day 2 Discussion Groups

Economic Costs of Anthropogenic Noise

Discussion 1 – Annie Linley

ISSUES	SOLUTIONS
Context of government targets for renewables	Different scenarios including BAU?
	Question for society?!
Holistic approach – need to have information from all sectors e.g shipping	
Need decision framework which captures industry – ecosystem perspective	Tools in development but may not influence government (apples and pears comparison)
Health and welfare	
Need evidence of noise effects/impacts – eg fishery nurseries / migration? / recruitment	Fieldwork (may not be able to establish cause and effect!)
	Continue – refine / improve
Is MMO on construction vessels worthwhile? (Cost-benefit)	
Is mitigation of pile driving worthwhile?	Industry to get grip on real costs of mitigation JIP?? April £4.5m ESRH (which they are doing)

Discussion 2 - Ken Collins

ISSUES	SOLUTIONS
Monetary value of “lost” ecosystems	Ecosystems services approach (DEFRA/NE…..)
Non-compliance with extra national legislation	
Awareness that noise is a problem	Education Websites network
Balancing costs of 1. shipping noise reduction with fuel/operating costs 2. offshore energy with price of electricity	Understanding costs (global) New technologies research Understanding complex inter-relationships
COST OF NOISE REDUCTION	Incentives? C.f. organic premium, food miles, carbon credits
QUIETNESS COSTS!	

A major determinant of the policy decisions and legislation developed to manage marine noise is the economic costs versus benefits of noisy activities. Economic benefits of shipping, windfarm construction, dredging, and other activities are less of a challenge to assess than economic costs. In general, costs of noise divide into operational costs (e.g. inefficiency of ship propulsion due to noisy cavitation), logistic costs (e.g. halting construction due to passing cetaceans), delays in development due to uncertainty or unclear planning process, and environmental costs (e.g. scaring fish from nursery grounds, disturbing foraging behaviour, effects to development).

The cost of noise needs to be put into context with climate change, and the Government's obligations to reduce CO2 emissions. Without offshore renewables the environmental costs could be far greater. The whole acoustic budget needs to be considered, pooling information from all sectors, so that the decision framework captures all industries and can lead to an ecosystem perspective. The ecosystem perspective also requires much more knowledge about chronic and subtle effects of noise, on fish and invertebrates as well as mammals. Particularly valuable would be knowledge about effects of noise on key locations or processes (e.g. nursery grounds, migration, recruitment, development). Two important questions that should be tackled first are: 1) Is it cost-effective to have MMO observers on construction vessels?; 2) Is mitigation of pile-driving noise worthwhile?

The working group felt that the cost of noise versus other issues was a question for society, and so public engagement and consultation is needed to make decisions about whether noise should be managed, controlled, limited, avoided with different activities and in certain areas. Perhaps business-as-usual is not that bad? Much more fieldwork is needed, including long-term studies of impacts of chronic noise to individual animals through to whole ecosystems. The recovery of communities following noise (e.g. after piledriving) is also a valuable research focus. Finally, it was noted that industry is already making serious attempts to address economic costs of noise, for example through the Exploration and Production Sound and Marine Life Joint Industry Programme (JIP) and by shipping noise being put on the agenda of the Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO).

Underwater Noise and the MSFD + Extrapolating from Science to Policy

Discussion 1 - Sophie Holles

ISSUES	SOLUTIONS
EU Directive: Good environmental status by 2020 11 Descriptions inc - NOISE (radiation) - litter - Sea bed integrity etc D11 = noise Define anthropogenic contribution to noise Standards Define if descriptions are suitable for assessing impact 63 + 125 Hz 1/3 oct bands 100 dB or 2012 baseline – doesn't seem so for some stakeholders Can you regulate characteristics of the environment better than the impacts? Inconsistency between MSFD and IMO regulations	4.Scientists can advise policy makers on indicators and their parameters for TARGETS 3.Test descriptors -> record broadband 10Hz – 120 kHz Define frequency range: dynamic range 2.Use Marine Spatial Planning process – integrate - decide on spatial and temporal units for monitoring in future 1.We need a more comprehensive noise audit Collate and synthesise the info we already have Advance science as well as comply with legislations

Discussion 2 – Phil Williamson

ISSUES	SOLUTIONS
1. Acute – more controversial 2. Ambient standards Global Environment Facility (GEF) More pragmatic approach - data reporting / register - monitoring - international integration - (idealogical / entrenched views)	<u>Integrated approaches</u> Role of Underwater Sound Forum Proof of concept Modeling acute impacts (large spatial scale) Biological effects – scaling up Mitigation: what contribution? Repository Scoping study Integrated marine observatory Existing buoys Cefas, Defra, MMO + industry Supergrid??

Issues:
The Marine Strategy Framework Directive (MSFD) is a European Union (EU) directive that was developed to promote sustainable use of the seas and conservation of marine ecosystems; each Member State must achieve or maintain Good Environmental Status in the marine environment by 2020. Measures must be in place by 2016, a monitoring programme in place by 2014 and by 2012 “Good Environmental Status” should have been defined and an initial assessment have taken place. Underwater noise is one of the 11 descriptors in the directive and we discussed some of the issues surrounding implementation of the MSFD with respect to anthropogenic noise, along with potential solutions and ways forward.

Although there are some data available, and some parties felt that not all of the available data have been made full use of, the anthropogenic contribution to underwater noise is not yet clearly defined. To this end we are lacking standards that are applied to data acquisition and usage on a sufficiently widely accepted scale. 63 and 125 Hz third octave bands with a threshold of 100 dB or the 2012 baseline have been highlighted for assessing Good Environmental Status, but these do not seem suitable for some stakeholders. It was suggested that we may be able to regulate the characteristics of the environment better than the impacts of noise, and that there could be better links between the aims of the MSFD and the International Maritime Organisation (IMO).

Solutions
We need a more comprehensive noise audit where we collate and synthesise the information that we already have.
We should integrate implementation of the MSFD with the Marine Spatial Planning Process and decide on spatial and temporal units for future monitoring.
We need to test whether the descriptors in the MSFD are appropriate. For this we should collect broadband recordings (10 Hz – 120 kHz) and use them to define frequency range and dynamic range most appropriate for monitoring.
Scientists must advise policy makers on indicators and their parameters for targets.
Finally, in order for science to successfully extrapolate to future policy we must aim to advance science as well as comply with legislations and existing policy.

Who needs to know? How to communicate + interact with the right people and engage the public on anthropogenic noise

Discussion 1 – Pippa Mansell

ISSUES	SOLUTIONS
Lack of awareness of the underwater environment	Multimedia – vision/video works
Difficulty of understanding the "physics" of noise	Use experts museums / wildlife trusts Different industry sectors
Is there a problem? Lack of awareness	Website – who is doing what? FATDIG? Support Underwater Sound Forum KE expand KTN c.f. CARN Evidence base
Acoustics vs biologists divide	Integrated research teams
Public cannot act directly to reduce underwater noise	Echosounders – switch off! Green blue – shhhh….
Industry and regulators need to understand problems and solutions	BBC wildlife article "Scrappage" on noisy ships! C.f. single hull tankers, ballast tanks

Discussion 2 - Mark Simmonds

ISSUES	SOLUTIONS
Low level of public understanding	Public engagement – emotive images and stories
Low levels of appreciation from policy makers	Keep it simple – detechnify Training and practice in communication (including students) ➔ build confidence
Low priority for action	General public need to know Proactive administrators (civil servants) who have access to the political level
Uncertainties	No undressing in public

The working group agreed that there was a need to communicate with the whole of society, noting that there was generally a very low level of understanding of marine noise issues and that this was affected by the remote and highly technical nature of the topic.

The profoundly different natures of the marine and terrestrial acoustic environments and the difference in our senses compared for example/in particular with those of marine mammals are also important factors in our appreciation of the issue.

We concluded that there was a need to de-technify wherever possible and that scientists engaged in this area had a significantly important role in explaining the issues to the public. A program of public engagement was in effect advocated. Whilst the general public cannot do anything to help this directly, it is worth noting that globally boat echo-sounders put more energy into the marine environment than any other anthropogenic sound source. Boat owners, through the RYA Green Blue programme could possibly have a switch off your echosounder programme to highlight this (in the same way as Earth Day - switch everything off for an hour)

Ultimately the point was to communicate with policy makers but given the low level of public appreciation there is little call from the public for more engagement in this area.

Modelling Population Level Effects of Noise

Discussion 1 – Andrew Gill

ISSUES	**SOLUTIONS**
Translation of data of individuals to population level effects	➔ Phylogenetic / functional groups
Different contexts may change noise threshold levels	➔ Overlay different threats with population surveys
Synergistic effects: noise not the only factor	➔ More monitoring data
Identify key functions / factors (i.e. biological functions)	➔ Fitness measures
Uncertainties	➔ Quantifying gaps in knowledge
Definition of a population	➔ Find robust approximation measures

Discussion 2 - Peter Tyack

ISSUES	**SOLUTIONS**
Going from behavioural change to vital rate	PCAD and SAFESIM Use elephant seals (etc) where parameters measurable (& photos)
Seals – ok-ish	Vital rates – body condition
Cetaceans - ?	– energetics – foraging success
Fish - ?? masking sound to find habitat and interspecies interactions	– reproductive output – go straight to vital rates and body condition
Crustaceans But recruitment counts, variable sensitivity	Experiments monitoring Identify life history bottlenecks
Compensation / trade-off control sites hard to find	Test sites / species Reward for reducing uncertainty – somehow
Biological significance of population effects	Allocate $ £ to things produce most uncertainty
recognizing the uncertainty	Physics and/or biology
Tying industry of interest to animal metrics -> big scale variability	PCAD needs time to mature / prove itself

In order to meet the requirements of the title of this working group there was much discussion about what were the component parts of the topic. The group were in agreement that the modelling had to have a solid basis hence appropriate data on which to base a model was the first key aspect decided upon.

The main issues were seen as obtaining sufficient data on individual response to noise that could then be scaled up to the population level. In effect this was dealing with finding groups of behavioural response or emerging patterns of response within a set of individuals. The group highlighted that the threshold level of noise that would result in some sort of response by an individual was highly context dependent; meaning that the threshold may be different even for the same animal if the ambient conditions are different. This then lead into a discussion about possible synergistic effect as noise is not the only stressor that the organisms will encounter. The effects may be exacerbated or altered according to the influence of other fats.

In order to determine how noise may effect individuals and then for this to be translated into a population level effect it was suggested that the key biological functions that are likely to be affected needed to be quantified. For example, the noise may affect the reproductive behaviour which then has the consequence of reducing the potential for mating and hence recruitment would be reduced. So it is important to determine the biological functions that may be affected.

It was recognised by the group that dealing with the level of uncertainty in determining effects on individuals and how they are manifest at the population level is critical to moving the science forward. There are a number of qualitative approaches to trying to understand uncertainty but what is needed are more quantitative (or even semi-quantitative) methods, which will require the right data to be collected.

The final issue focussed on how a population is actually defined. Many organisms have spatial and temporal changes, such as in distribution, that could have a major influence on whether any given organism is regarded as within the population or not.

In terms of solutions the group were able to suggest a number of options. In order to deal with the issue of how noise may have population (or ecological) level effects it was suggest that rather than focus on individual species it may be more appropriate to consider phylogenetically similar species and/or species within the same functional groups. Whilst this may not provide the answer for a specific species it does increase the amount of data that could be collected and interpreted appropriately for a topic that has a dearth of knowledge. Hence more data could be gathered that would be useful for modelling purposes.

In terms of the context dependent effects, the discussion centred on undertaking a number of population surveys under circumstances where different threats and combinations were present. The idea here was that a great amount of targeted monitoring could provide data required to properly deal with synergistic (and ultimately cumulative) effects.

A number of key functions that may be affected by noise could be quantified through fitness measures for which there are a number of different methods available.
For much of the above it was recognised that gaps in the knowledge needed to be identified and then actions put in place to fill these knowledge gaps through appropriate data collection.
The solution to defining the population was to find robust approximation measures and consider the right spatial and temporal scales for the species in question.

Data sharing, confidentiality and IP

Discussion 1 – Vincent Janik

ISSUES	SOLUTIONS
Classified data held by the Navy	
Date are currently distributed across many organizations	Coordinated portal on metadata website as a catalogue (MEDIN)
Quality control Shared sampling protocols What to keep?	Identify data that might give best results or in danger of being lost
Standardization of meta data e.g. transducer calibration sheets ? xxx	Shared sample protocols Standard metadata structures
Data security (e.g. ensure tamper-proof depository)	High profile successes
Data access Data collection for profit by government agencies Data coordination across countries	Good science from ‘hidden data’ will encourage others

Discussion 2 - Pippa Mansell

ISSUES	SOLUTIONS
Commission of work: Ownership of data	Mechanisms for accessing data? Assess quality? -> central archive – formatted
Different funders -> different archive policy Access to data? Who?	Procedure for consent and sharing / release – STANDARDISE
Availability of data: time frame	KE: decrease costs / sharing info funding of archive
Data quality – QV of standard communication flow	Open up communication flow and key contacts
Implications of previous studies	Interaction with ‘collectors’ of data – correctly used
Interpretation of data (mis-use)	UK Guidelines – ‘levels’ of agreement
Contract wording and interpretation	Oceans 2025: format of data Licensing agreement -> BODC
	Payment agreement? – restricts access legal team – check clauses

Several issues regarding data storage and sharing have been identified. Currently, valuable data sets are distributed across institutes, often with very different standards of archiving or indexing. Institutions may be reluctant to contribute data to a central access point since data ownership and IP issues are difficult to resolve. The distributed storage of data has its advantages (i.e. losing data in a flood or fire is less likely). We concluded that a central catalogue of what is being held at different institutions would be a good solution to make data accessible. Ideally such an effort would be international, but can be started on a national level. Control over data distribution, data security and data sharing agreements would stay with the institution, but researchers would be able to search the catalogue to see what is or is not available. One aim that we should work towards is a standardization of metadata. This includes keeping calibration sheets for transducers and making them available with the corresponding acoustic data. Ideally, one would also want shared data collection protocols. The best solution here would be to give an example of the desired protocol that researchers should use unless their study requires a different one. This could also be provided through the central catalogue. Such a protocol would also help to decide what data to keep. The design of such a protocol would probably require a workgroup that develops a proposal and then seeks input from the rest of the community. Quality control should also be a consideration for such an effort. An important first step would be the identification of valuable data sets that are currently at risk of being lost. Unresolved problems in such a standardization effort are the use of data for profit and requirements for classified data. One or more high-profile publication coming out of pooled data set might give other scientists an incentive to contribute an index of what data they have to a central catalogue.

Propagation and Dispersion of Anthropogenic Noise in Shallow Water – Paul Lepper

ISSUES	SOLUTIONS
Shallow sediment propagation Distributed sources Inputs to models Uncertainty Can't do lots of measurements for validation Model used to validate model *(see appendix for diagrams)* > 40km complex bathymetry measurement of operational noise	Validate propagation models Use large array of hydrophones How important is it? Sensitivity analysis (wave height) Standardization of seabed data (access to data) Sediment types International xxx Comparison of models (open source)

The need for understanding of acoustic propagation models in context of marine renewable requirements was outlined by workshop participants. Acoustic models have been widely developed for sonar operations to predict a loss function. These in combination with suitable source characteristics are used to estimate the effective received levels at a point some distance from a source. This is important due to the cost and practicalities of conducting many experimental measurements in the field is prohibitive. In the case of marine renewable often in shallow water strong interactions of the sound field with both the surface and seabed exist often making that loss function complex. In addition energy may be directly injected to the seabed and later emerge into water column. In many cases the use of simple geometrical spreading models may not adequately describe the radiated sound field particularly in shallow water and/or complex bathymetries often seen in renewable developments.

Some users have adapted well established deeper water models incorporating bathymetry, sediment and water column properties including through sediment propagation to use in shallow water. Many of these models however assume a single infinitely small point 'mono-pole'. In casesvsuch as pile driving for wind turbines construction or a large surface wave energy system could be consider a distributed source over many 10's or 100's of meters. The prediction of sound fields close to the source, often where highest levels exist, may be within a sources ' near field' and therefore may not be adequately described by a single mono-pole source model at these shorter ranges. The need for understanding the transition from complex near field situations near a distributed source to a far-field case where mono-pole source description can be adequate, was highlighted. The size of the near-field is likely to be related to the relative size of the source, water depth and its relative distribution in air /water column and the seabed and a need for understanding of what models to use when was identified. Both detailed experimental measurement and modelling approaches such as multiple and full source models where put forward as potential solutions to understanding near and far field interaction for renewable energy systems. It was also highlighted that the validation of model accuracies at much larger ranges (greater than 40km) is beginning to be needed as more behavioural response data emerges at theses ranges. The conducting of experiments using large scale acoustic ranges to validate different model operation in shallow water was identified as one potential solution.

Another key component of use of models to predict sound fields around renewable systems operation was the collection of high quality input data including sediment type, water column properties and source characteristics such as construction and operational noise characteristics. This data collection should ideally be internationally standardised and made accessible allowing different users to compare and model as appropriate. Similarly the models themselves should be compared identifying uncertainty and sensitivities for example wave height, how important is it? and what value should I use? Similarly the use of open source models would allow greater transparency between modellers allowing data comparison and validation.

Standards: Definition and Practice - Paul Thompson and Phillipe Blondel

ISSUES	SOLUTIONS
Measurement standards being developed but not agreed / easily available	Draft documents to be made available through NERC KE portal
Particular difficulty measuring particle motion	Need to calibrate particle velocity sensors
Problem is that this is novel area of work	Could produce a device to calibrate
Also need standard for measuring different type of underwater noise to ensure results are reproducible / comparable	Explore potential for industry partnership
	MEDIN website has standard metrics for reporting noise measurements
	Explore whether Defra could agree on reporting – develop our own UK or TNO
	Requires wide consultation

Assessments of the impact of underwater noise on marine environments depend upon repeatable and clearly described measurements of natural and anthropogenic noise. Unlike terrestrial noise, however, there are currently no internationally agreed standards or equipment for making and reporting measurements that permit transparent comparison of different datasets. This currently constrains interpretation of many studies involving sound pressure measurements, and is a particular issue for near field studies that need to measure particle velocity.

There are on-going efforts, at national and international levels, to define a general ANSI standard, but this is likely to take some years. In the meantime, the workshop identified several authoritative standards that researchers can use to support investigations of underwater noise. These include technical reports by key industries (e.g. Erbe, 2011), textbooks (e.g. Ainslie, 2010) and Internet-published guidelines (e.g. MEDIN, 2011). The consensus was that more could be done to publicise existing standards and recommendations, for non-specialists and researchers new to the field. Efforts were also needed to make these standards widely available, potentially through the Natural Environment Research Council's Knowledge Exchange Portal (https://ke.services.nerc.ac.uk/Marine/Pages/Home.aspx) and information repositories such as the long-lasting Ocean Acoustics Library (http://oalib.hlsresearch.com/).

Particle velocity measurements are an emerging field of interest for ambient noise and impact studies, and the calibration of particle motion sensors and comparison with acoustic pressure variations has proved particularly challenging for bioacousticians. One solution explored during the workshop was the design of a generic calibrating device. This could then be made available as a central facility in partnership with industry, thereby supporting the development of standards for particle velocity measurements.

Ainslie, M.; "Principles of Sonar Performance Modeling", Springer-Praxis: Chichester (UK), 800 pp., 2010

Erbe, C.; "Underwater Acoustics: Noise and the Effects on Marine Mammals", http://oalib.hlsresearch.com/PocketBook%203rd%20ed.pdf, 2011 [last accessed 17 February 2012]
MEDIN, "Marine Environmental Data & Information Network: Data Guidelines", http://www.oceannet.org/marine_data_standards/medin_data_guide.html , 2011 [last accessed 17 February 2012]

CLS/SDS
25.4.12