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ENV.D.2/FRA/2012/0025: Impacts of noise and use of propagation models to predict the recipient side of noise

Draft Workshop Report – For Participant Comment

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1 Introduction

A workshop with the title **'Propose methodologies and guidelines on how to evaluate impacts of noise on marine biota'** was held in Brussels on 10-11 April 2014 within the contract "*Impacts of noise and use of propagation models to predict the recipient side of noise*" (DG ENV 1109.05/659011/SER/C.2)

The workshop co-chairs were Dr. M. Tasker (JNCC) and J.F. Borsani (CEFAS). The aims of the workshop were:

a) Discuss and propose a roadmap towards defining Good Environmental Status (GES) for underwater noise,

b) Identify knowledge gaps and define research needs to address the impacts of underwater noise on marine biota and,

c) Provide guidance for important features and considerations that a proposal related to the effects of underwater noise should have when submitted to the EC for funding.

37 delegates from Industry, Academia, NGOs and DG Environment attended and provided their own perspective to the objectives of the workshop. Five international experts provided insight respectively into the fields of effects of noise on invertebrates, fish, marine mammals; into the PCAD (Population Consequences of Acoustic Disturbance) framework as well as into noise modelling and mapping.

Thereafter one full day was dedicated to discuss the topics in break-out groups each of which had the task to provide its perspective on each topic. The results of the discussions were merged and then presented and discussed in plenary. The outcome of the discussions by objective is provided in the following.

1.1 Purpose of this report

This report is intended to be an internal document to a) report on the different views and aspects on the workshop objectives as expressed by the delegates, and, b) to inform Task 3 of the project.

Task 3 is described as: "Propose a roadmap to wards defining sound limits for GES". In particular:

a) Prepare a roadmap towards a sufficient assessment of impacts of underwater sound for all marine biota and at all levels (individual, population, ecosystem) in order to define operational targets or GES criteria (i.e. limits for impulsive and ambient underwater sound). Each element of the roadmap (i.e. proposed new research) should be specific and accompanied by an estimation of cost and a recommendation of the relevant framework for its accomplishment.

b) Prepare input for a possible revision for the Commission Decision on Descriptor 11.

2 Workshop Objectives

The three main objectives of the workshop were:

1. **Discuss and propose a roadmap towards defining Good Environmental Status (GES) for underwater noise.**

Work on MSFD descriptor 11 on emissions of energy has so far focussed on developing indicators of the spatial and temporal patterns from emissions of two forms of anthropogenic underwater sound. So far no links have been made to the consequential change in status of the marine environment and its biological components. In some jurisdictions, criteria for defining sounds that have adverse effects on biota have been developed, but none have been developed that would provide a status indicator for the ecosystem as a whole, or for assessing the cumulative effects of sound. Work to develop standards to measure underwater sound is still underway.

(1.1) Review progress towards a consensus for standards to measure and describe underwater sound.

(1.2) Review progress in integrating the results of 'field' Controlled Exposure Experiments (CEE) and other sources of information with models describing population and/or ecological effects.

(1.3) Consider the usefulness of thresholds for describing Good Environmental Status.

(1.4) Draft a roadmap (or roadmaps) towards defining GES.

2. **Identify knowledge gaps and define research needs to address the impacts of underwater noise on marine biota.**

Funds may exist within the European Union to support research that enables the attainment of GES. Considerable research is in progress (or in later stages of planning) elsewhere. The workshop should aim to inform the European Commission of its views on priority research areas.

(2.1) Prioritize gaps and define research needs to address the achievement of GES, taking account of existing or planned projects.

3. **Provide guidance for important features and considerations that a proposal related to the effects of underwater noise should have when submitted to the EC for funding. This objective will take a lesser priority at the workshop.**

It is likely that any proposals relating to underwater noise that are submitted for funding will be assessed partly by non-specialists. There are important features that will be common to most proposals for projects on underwater sound (e.g. calibration, use of standards, testing of models). Guidance will be of use to both those that submit and those that review the proposals.

3 Workshop

3.1 Presentations

Five presentations were given at the start of the workshop by experts in their respective fields:

1. Professor Michel André, UPC. "Filling knowledge gaps with invertebrates."
2. Dr. Michele Halvorsen, SCA Ocean Sciences Inc. "Acoustic Effects on Fish and Data Gaps."
3. Dr. Christine Erbe, Curtin University, Perth. "Noise impacts on marine mammals—what do we know?"
4. Professor John Harwood, PDAD, University of St Andrews. "Forecasting the population-level consequence of acoustic disturbance for marine mammals."
5. Dr. Kevin Heaney, OASIS. "Acoustic Forecasting: Capabilities and Environmental Sensitivities."

The presentations are available at: <WEBLINK TO EC PAGE TO BE INSERTED ONCE PRESENTATIONS ARE UPLOADED>

4 Summary of Workshop Conclusions

The workshop attendees were divided into three break-out groups, following the presentations, to discuss each of the three objectives in turn. The summary of the priorities identified by each group are reported in the following merged by objective as reported by each group.

The results of the workshop will be used to inform Task 3 "Propose a roadmap to wards defining sound limits for GES".

4.1 Objective 1:

Discuss and propose a roadmap towards defining Good Environmental Status (GES) for underwater noise.

(1.1) Review progress towards a consensus for standards to measure and describe underwater sound.

(1.2) Review progress in integrating the results of 'field' Controlled Exposure Experiments (CEE) and other sources of information with models describing population and/or ecological effects.

(1.3) Consider the usefulness of thresholds for describing Good Environmental Status.

(1.4) Draft a roadmap (or roadmaps) towards defining GES.

1.1: Documenting standards

- Itinerary of EU standards (from current relevant EU project outputs) (Standards actually available are listed in Tables 1 and 2)
- Consideration of major international project outputs to help identify / predict and refine potential EU standards within areas of limited data knowledge.
- Re-define terminology for better clarification more widely throughout EU (continuity of terms).
- Important to standardise ambient sound and modelling techniques.
- Combined (measurements & modelling), approach to monitoring standards required
- What is it we need to measure?
- How to implement it? (e.g. seismic surveying / risk registers)
- Standardised monitoring requirements
- Defining the source of noise

- Record of mitigation measures (widespread mitigation measures will have impacts upon measurement standardisation e.g. level of pile driving small fine-scale issue in comparison to oceanographic seismic surveys)
- MSFD should have an "alert system" e.g. register numerous accounts of events spatially, but not specific small-scale localised noise concerns.

Table 1 and 2: Inventory of national and international measurement and terminology standards relevant to underwater sound (EU Noise Impact Workshop, Brussels)

Authors: M A Ainslie, S P Robinson

Version: 0.3, date: 11 April 2014

Table 1: Existing standards

	Terminology and reference value	Reference values and frequency bands	Measurements and measurement systems
National standards (DIN, BSI, ANSI, GOST R)	ANSI S3.20-1995 Bioacoustical terminology ANSI/ASA S1.1-2013 Acoustical terminology DIN 1320 Acoustics – Terminology (1997, in German) R50.2.037-2004 Underwater acoustic measurements – terms and definitions (in Russian)	ANSI S1.8-1989 Reference Quantities	ANSI/ASA S12.64-2009/Part 1, 2009. Quantities and Procedures for Description and Measurement of Underwater Sound from Ships - Part 1: General Requirements, American National Standard Institute, USA, 2009 ANSI/ASA S1.20-2012, Procedures for Calibration of Underwater Electroacoustic Transducers, American National Standard Institute, USA, 2012.
International standards (ISO, IEC, ICGM)	ISO 80000-3:2006 Space and Time (level, decibel) ISO 80000-8: 2007. Quantities and units - part 8: Acoustics, International Organization for Standardization, Geneva, 2007. ISO/TR 25417:2007. Acoustics - Definitions of basic quantities and terms. International Organization for Standardization (ISO), Geneva, 2007.	ISO 1683:2008 Acoustics – Preferred reference values (sound in air, plus structural vibrations) IEC 61260 (EN 61260), Electroacoustics - Octave-band and fractional-octave-band filters, International Electrotechnical Commission, Geneva, Switzerland, 1996.	ISO/PAS 17208-1:2012 Acoustics - Quantities and procedures for description and measurement of underwater sound from ships. Part 1: General requirements for measurements in deep water, International Organization for Standardization, Geneva, 2012. ISO1996-1: 2006, Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment procedures. International Organization for Standardization, Geneva, 2006. IEC60565: 2006 Underwater acoustics-Hydrophones -

IEC 60050:1994, International Electrotechnical Vocabulary, part 801:
Acoustics and Electroacoustics, (section 801-32 covers terms for underwater acoustics), International Electrotechnical Commission (IEC), Geneva, 1994.

Calibration in the frequency range 0.01 Hz to 1 MHz, IEC 60565 - 2006 (EN 60565: 2007, BS60565:2007), International Electrotechnical Commission, Geneva, 2006.

IEC 60500: Underwater acoustics - Hydrophones - Properties of hydrophones in the frequency range 1 Hz to 500 kHz (currently at CDV stage, revision of IEC60500:1974 IEC Standard Hydrophone)

JCGM 100:2008, Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), joint publication by BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML, 2008. Available from www.bipm.org JCGM 200:2012, International vocabulary of metrology - Basic and general concepts and associated terms (VIM) 3rd edition, joint publication by BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML, 2012. Available from www.bipm.org The International System of Units (SI), Bureau International des Poids et Mesures (BIPM), Paris (brochure available from www.bipm.org).

Table 2: Work in progress by the Standards Institutes to update standards listed in the Table 1

	Terminology and reference value	Reference values and frequency bands	Measurements and measurement systems
National standards (DIN, BSI, ANSI, GOST R)	ANSI S3/WG 73 (review of S3.20-1995 Bioacoustical Terminology)		
International standards (ISO, IEC, ICGM)	ISO/CD 18405 Underwater Acoustics - Terminology	ISO/DIS 1683 (includes reference values for water) ISO/DIS 1683:2013 Acoustics – Preferred reference values … (DIS)	ISO/DIS 16654.3 Ships and marine technology — Measurement and reporting of underwater sound radiated from merchant ships — Survey measurement in deep-water ISO/DIS 17208 Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for deep water measurements used for comparison purposes WG3

notes

#1 ISO standards are not consistent with IEC standards (eg the ISO definitions of “sound pressure” and “sound pressure level” are different from the IEC definitions of these terms)

#2 ISO standards are not all consistent with one another (eg ISO 80000-1:2009 contains a normative Appendix that deprecates terminology introduced in ISO 80000-3:20060; progress towards the ISO underwater acoustics terminology standard presently under development by ISO/TC 43/SC 3/WG 2, is hindered by this inconsistency. Development of this terminology standard would be facilitated if this inconsistency in ISO 80000 were removed. The ISO 80000 series is presently under review. Participation by one or members of ISO/TC 43/SC 3/WG 2 would facilitate progress towards a terminology standard. Of particular importance are the definitions of “level” and “decibel” in ISO 80000:3-2006.

1.2 : Integrating results of field experiments and other sources.

- How to translate effects of field experiments to chronic effects of individuals at population level?
- Lack of data here so "expert judgement" models required. Exception to the rule is beaked whales in relation to being able to predict lost foraging opportunities (through absence of number of daily routine foraging dives), however this is a special case and rare!
- Data on fish is poor – need to models to predict effects by different regions, areas, habitats, fishing pressure, noise exposure, behaviour state, feeding, breeding ambient sound etc.
- Time budgets / foraging behaviour / energy use
- Results that don't come from field experiments can be used to validate models (e.g. lab experiments, Michelle Halvorsen studies / juvenile fish lab research.
- Don't necessarily need field experiments for many fish species if plentiful controlled lab baseline studies undertaken (not relevant for larger fish species and marine mammals though to larger extent where field trials are critical).
- Noise exposure experiments involving mesocosm work required and a good baseline (starting point for further more open sea research. Can identify short term behaviour in such experiments and set standards to allow progression of more complex open sea studies.
- Tony Hawkins – field based wild behaviour in lock experiments (naturally enclosed environments for monitoring noise and behaviour – potentially highly valuable)

1.3: Consider usefulness of thresholds.

- Need to first of all identify the metric!
- Thresholds can give a probability of error using best possible data available.
- Useful example: Step function used for beaked whales (John Harwood's research)
- Threshold dependent on many variables e.g. habitat
- Sound maps overlaid with critical areas / hotspot areas
- Environmental sensitivity maps could prove more useful
- Dose responses are highly useful, thresholds less so. A shifting dose response can have an even greater effect.
- Precautionary statements for MSFD, may be required if you cannot set thresholds e.g. defining what are the most important measurements based on specific ecosystem
- Using "Expert Judgement" model you could predict standards by region to set standard precautionary thresholds and identify gaps.

- Could include shipping lanes / traffic and choose between specified indicator species (most sensitive, most abundant etc)
- A combined ecosystem approach to thresholds could prove useful.
- For regulation management you need “action based thresholds”
- Thresholds are necessary but not desirable.
- Set thresholds would be unlikely to be relevant over a wide geographical area. Maybe better by sub-regions?
- From a regulatory management view thresholds are useful, but from a biological perspective there are a lot of issues (e.g. geographical, ecosystem differences), that result in such thresholds being floored.

1.4: Road Map:

1) Ways of measuring ambient sound
2) EU register of noise sources (this should already be in place by each member state)
3) Implement register for EU sources of noise
4) Standardisation of:
    - Environmental impact
    - GES
    - Development of standardising
    - Current and future Knowledge outputs (modelling & measuring)
5) Knowledge of potential adverse effects (as a traffic light system). Use species which are easy to monitor (e.g. within a constrained spatial area / localised), Priority effects/priority species, what are the receivers?
    - Define / standardisation of effect
    - Measurement of adverse effect (lab and or field experiments), dose response assessment for overall risk.
    - Modelling; noise maps/masking maps, define GES in terms of an acceptable level
    - Thresholds – define the level of masking that is acceptable, i.e. masking maps for sensitive species. What level of masking is critical?
    - First stage would be to map the noise (ambient and impulsive). Second stage would be to map the species.
    - Masking maps for specific species (i.e. fish). For example, first step would be to monitor ambient noise. The second step would be to model communication space of spawning. Look at the statistical data. Percentile view of ambient noise. Estimate the

communication range for the lower percentile and then the higher percentiles (have a different map for different percentiles). Key question – over what communication ranges do males attract females?

6) GES = implementation of many factors (e.g. recruitment of fish – larvae to adult life history phases), i.e. we need to consider other pressures not just noise alone.
7) Experiments required to monitor adverse chronic effects
    - Long-term ambient noise levels
    - Larvae – to adult behaviour responses
    - Quantify baseline measurements prior to determining chronic exposure effects
    - Population based studies required
    - "expert judgement" modelling alternative approach
    - Social – economic requirement (fishing activity)

Summary:

- Set up register that gives you a baseline of noise
- Followed by measurement of trends for ambient noise
- There will still be a huge variance within any initial baseline measurements (e.g. seasonal etc), so useful to model / predict potential variances (time & space modelling)
- Distribution measurement array

Description of what is actually happening in the environment (sub region), in question:

- Acoustic surveying
- Activity register
- Shipping traffic
- Data already collected for region
- Oceanographic mapping
- Nutrients / dose responses
- Eutrophication – defining limits
- MSFD descriptors to manage the problem within reasonable bounds
- Measure and monitor individual pressures; need to have a goal (end product) of the roadmap i.e. the percentage of habitat loss.
- Defining potential pressure indicators for potential GES

Must first document what monitoring has been already undertaken, this will then help to identify trends, potential foodweb dynamics: it is important to look at whole ecosystem effect not just at individual species level.

Must use a combined approach e.g. understanding of regional foodweb dynamics, then impose/add pressures e.g. noise, masking, oceanography, chemistry etc.

What are the impacted effects on a species as a result of the 'pressures' to the regional foodweb / ecosystem.

Availability of resources to the species in question hugely important factor – e.g. animal might cope with exposure / chronic effects if food resource is abundant within region: however if it is restrained then the chronic effect is likely to increase resulting behaviour shifts.

4.2 Objective 2:

Identify knowledge gaps and define research needs to address the impacts of underwater noise on marine biota, in relation to:

1. **Low and mid-frequency impulsive noise:**

It was suggested that a selection of the most relevant (indicator) and representative species needs to be made, based on conservation status and/or sensitivity. For shallow/inshore waters, focus may be on cetaceans (e.g. harbour porpoise), and selected species of fish that may be sensitive and/or commercially important (e.g. herring, cod; partial overlap with D3-populations of commercial fish). For deep/offshore waters, focus could be on beaked whales, baleen whales and fish. Further, it was suggested that one species could be selected out of the following groups: high (i.e. porpoises), mid and low frequency cetaceans (i.e. baleen whales), pinnipeds and fish (more than one). Further research is needed for clupeid fishes (herring) as they are sensitive to sound and therefore these are a good indicator group. No concrete proposal for indicator species was made.

There is a requirement for an improved risk assessment framework. Present impact assessment may contain exposure assessments and to some extent there is information on direct/individual responses, but the implications for populations or ecosystems is still unclear. The group noted the progress made in projects like PCoD. For the selected species, relation between direct responses at the individual level and population / ecosystem effects needs to become clear. It was suggested that studies on energetics as important fitness parameter for different species could be useful.

Per region there are differences of distributions of species. The group noted that there is a bias, most attention now is on species in NW-Europe, for many of these species there is information on responses to noise exposure, but there should be more attention to describe pressure/impact relations parameters of Mediterranean species (fish, baleen whales). How do we help all major Mediterranean countries with management decisions? It was noted that there are often communication difficulties. Also important to consider countries outside Europe.

- Behavioural disturbance was identified as a priority issue, as this may have ecosystem effects.
- Potentially, there may be auditory effects for some (important) species like harbour porpoise that should not be neglected.
- The group noted that effects to fish like acoustic trauma may happen at lower levels than mostly assumed, at lower level than TTS. Still, injury effect with fish are probably of lower concern at ecosystem scale because of the high levels needed to induce these effects.
- Habitat modelling and acoustic modelling need to come together. It was noted that there are knowledge gaps for deep-water animals.
- Biota groups of table 1 that are of lesser concern are fish larvae, turtles (indications of high levels needed to induce effects). For birds no information is available due to the lack of studies addressing effects on diving birds.
- The effects on invertebrates are not well known, for some this could be a priority because they are commercially important species (partial overlap with D3- populations of commercial fish), notably crustaceans and scallops.
- More work on masking is needed. For example, what are the population effects as a result of masking? Knowledge in general on population effects is needed.
- Need to look at the impacts of low and mid-frequency impulsive noise on vocal fish in terms of reproduction for key species. For example, the fitness of an animal could be affected.

2. Continuous low frequency ambient noise:

- Main effect that raises concern related to elevated (i.e. increased by anthropogenic activities) ambient noise levels is masking (interference with communication, echolocation, navigation, predator/prey relations, interaction with social behaviour, e.g. schooling); in theory masking can be calculated to some extent but whether communication ranges are effectively reduced is still not clear.

- The long term chronic effects (i.e. stress, coronary heart disease) and physiological impacts of chronic noise exposure are unknown for marine biota.
- At what level does TTS and PTS occur? What level does the noise exposure have to be when there is no recovery?
- Shipping lanes leading to displacement/habitat loss may be an important effect in some regions.
- For masking, both direct effects on individuals and population effects are largely unknown.
- Effects of ambient noise like reproduction of vocal fish, reducing fitness should be addressed.
- Groups of sensitive species were discussed: clupeid fish like herring, vocal fish, potentially some dolphins and low frequency species like baleen whales. Species for which effects are not well known and therefore of concern may be invertebrates, some may be commercially important (crustaceans; partial overlap with D3- populations of commercial fish), and there are indications of potential effects at low level with cephalopods.
- As with impulsive noise, there is no need to study all species, but based on conservation status and/or sensitivity a selection of species can be made. For shallow/inshore waters that may be fish, potentially some dolphins species. For deep/offshore waters focus could be on baleen whales and fish. Invertebrates should also be a priority because they are of commercial value.
- It was highlighted that continuous ambient noise is important for fish larvae and shellfish larvae.
- The TSG Noise report (monitoring guidance) addressed averaging methods, describing pro's/cons of different methods. At present, it still unclear what the most biologically relevant measures are, this should be addressed in the ambient noise monitoring programmes being set up by EU Member States.

3. General research topics:

- For specific species (invertebrates, fish) and situations (bottom species, piling) not the pressure but the particle motion seems to be the relevant factor. This is not commonly addressed, and these parameters are often not monitored or determined.
- Transfer data from test tanks/laboratory studies to the field/wild may be specific research topic, since this may aid in more rapid development of knowledge. Research in a laboratory setting has a number of advantages, the context is better controlled and relation between specific parameters and effects can be identified. In many situations, use of test tanks may

be cost-effective, or it may provide guidance for field studies. For physiological parameters results can be considered to be representative for the field situations. However, application of the results of behavioural studies is desirable but needs to be validated. It was agreed that a combination between tank and field experiments is needed.

4. <u>Other issues:</u>

- The group noted that addressing mitigation could be a priority research topic, but this was not the scope of this meeting and not further addressed.
- The group noted that other indicators of noise than the two indicators of the CD 2010 might be needed. Since this is identified in the work plan of TG Noise this was not further discussed.

Prioritizing Research Gaps

1. Determine population effects of low- and mid-frequency impulsive noise on marine life in order to establish targets (might be used already for 2018/2021 MSFD cycle)
    a. Relation of direct responses and population effect for indicator species like porpoises and fish
    b. Improved knowledge of response of deepwater species (e.g. baleen whales and beaked whales)
    c. Develop knowledge on effects of noise on selected species of invertebrates
        c.i. Commercially important species like crustaceans
        c.ii. Potentially sensitive species like cephalopods (others)

2. Effects of elevated ambient noise levels on marine life, in order to establish targets for future MSFD cycles.
    a. Develop knowledge on masking effects of elevated ambient noise levels
        a.i. Baleen whale communication
        a.ii. Other receptors

    b. Develop knowledge on effects of elevated ambient noise levels on fish communication
    c. Mindfully measure both particle motion / acoustic pressure during any experiments for future research to create greater long-term understanding.
    d. Establish the relation between reduced communication and fitness in order to determine population effects

e. Broad ecosystem scale approach needed so acoustic pressure a more useful tool of measurement for GES levels (highlight particle motion as a knowledge gap at the fine-scale).

3. Determine which additional parameters (other than currently used pressure parameters) are needed to characterise sound sufficiently
    a. Effects of particle motion on sensitive species (fish, invertebrates)

4. Develop methodology to enable improved use of results of laboratory studies, enabling improved use of behaviour studies in test facilities

Research Gaps as considered from an animal group perspective

Marine mammals:

Biggest Gap for Marine Mammals: Chronic effects of noise exposure – needs to be defined e.g. stress etc. and how best to measure it in the wild (e.g. identification of a suite of biomarkers required, but not easy to determine, e.g. cortisol levels). Anything that doesn't cause death is essentially a chronic behaviour effect to marine mammals.

Two different things: Chronic effect (harder to measure) and chronic exposure (easier to measure).

Dose response relationships to measure physiological effects e.g. stress health, respirometry, dive behaviour.

Cortisol – remote monitoring, knowledge gap that isn't likely to be achievable.

Priority of Behaviour response values for marine mammals required:

- Relationship between behaviour responses and (chronic or acute) effects and resulting effects in the environment
- Putting the behaviour into context of an event (e.g. feeding, breeding etc)
- Is there a relationship between average exposure to noise and population effects (at the behavioural level)

Significantly more information on marine mammals than compared to fish so need to re-define the colour of the table (e.g. fish in red due to severe lack of data but marine mammals more orange)

Fish:

Priority of evidence gaps for fish: More behavioural and masking studies in the semi-constrained (mesocosm trials) and open sea (wild trials)?

- Using tagging experimental studies to track broad spatial patterns of distribution to model up to population level.
- Accelerometer tracking to track immediate behaviour responses to sound (Speak to Vicky)
- Population / food web level – behaviour and population level effects (need to combine interactions).
- Current literature often not directly applicable in terms of regions, habitats, field controlled exposures, lack of information – evidence gaps.
- More field based but also lab based experiments – required to create greater understanding of dose response levels on fish in relation to behaviour effects.

Fish Larvae (Pelagic larvae)

Fish larvae are a research priority since it is not clear if potential impacts (such as growth response rates, mortality) have an effect at the population level.

Measurement between sound exposure and fitness an essential requirement for all marine biota.

Identify predictions of small fish protection measures from noise disturbance

Sea Turtles (highest conservation status – so important concern)

Sea turtle – subtle behaviour responses to seismic noise.

More secondary responses in relation to invertebrate prey responses.

Crustaceans (evidence needed for behaviour responses)

Priority is behaviour – (need to understand the hearing / detection rate within behaviour research)

Sea Birds:-

Priority – behaviour changes in foraging responses.

Examine noise by Identification of relevant indicator species for monitoring GES.

What is the value of indicator species – most abundant / most vulnerable / most responsive / ranking.

4.3 Objective 3:

Provide guidance for important features and considerations that a proposal related to the effects of underwater noise should have when submitted to the EC for funding. This objective will take a lesser priority at the workshop.

The following is intended to serve two purposes:

i) For non specialists to check proposals

ii) For proposal author to understand what it should contain (e.g. calibration section)

The workshop participants identified the following items as important features and considerations which would need to be addressed in any proposals related to underwater noise effects. It should be noted that not all items need to be met by each proposal.

1) Calibration: Frequency spectrum over frequencies of relevance and interests. Traceable standards and procedures or auditable calibration for hydrophones
2) Transmission conditions:
   - Bathymetry
   - geo-acoustics
   - oceanography
   - sea surface conditions
   - local weather conditions
3) Dose relationships – use received levels rather than modelled levels wherever possible
4) Source characteristics - outline probability of bias, issues using modelled data. Understanding any bias in results through using models.
5) Standard of units and terms (calibration, measurements and terminology)
6) Targeted needed research for implementation – (needs clarifying here)
7) Behaviour – studies in context (e.g. for feeding, population rate)
8) Description of how contextual information will be gathered (e.g. ensuring there is no observer effect)
9) Proposal – have you recognised observer effect? How will it be quantified and assessed.
10) Modelling – standards (what are the assumptions or approximation of the model, benchmarking of the model; what is there approach to source levels for the models).
11) 2D & 3D measurements – measuring the perceived whole oceanography / physical environment. Ensure measurement at a range of depths throughout environment.
12) "Masking" – very few studies (signal processing constraints)

13) Displacement used as a proxy – vertical, horizontal – and combined with a state (e.g. ceased feeding behaviour)
14) Impact of "Self noise" around your system (set up), ensure calibration and tested control measures to understand your set up prior to measuring / recording noise.
15) Knowledge of the natural ambient noise is key prior to starting projects
16) Mitigation measures – need to define what you are mitigating against.
17) Indicator of shipping mitigation
18) Studies on the source – knowledge of source characteristics –
19) Refraction considerations for sound characteristics – relate to mitigation measures.
20) Finding out what part of noise spectrum causes the effect to marine biota
21) Environmental uncertainty (to defining modelling)
22) Approach has to be treated scientifically to clarify levels of probability / uncertainty / bias to the range of levels measured (e.g. for source, environmental state, effect, model error).
23) Standard QA of results and reporting.
24) Publicly available datasets – to allow open analysis of results for future work.
25) Problems of modelling using non-peer-review techniques – needs to be evidence based / QA'd.
26) Fish experiments – need to show evidence based understanding for measurements required to accurately perform fish behaviour studies (e.g. the requirement to include "near field measurements" & quantify "particle loss").
27) The proposal should highlight its socioeconomic value, stakeholder engagement, impact on policy, impact on achieving GES.
28) In relation to biology, ethics, repeatability, context should be clearly defined.

4.4 Conclusions:

The above list of items for each objective was discussed in plenary. Comments contributed by delegates were considered in each list. Additional comments are listed below:

- Particle motion is an important research topic. It may not be vital for short term (maybe not for the first MSFD cycle) but possibly in the future this will be something to consider.
- It is important to consider ecosystem level effects and food web dynamics – linkages within the food web.

- Crustaceans that are not key commercially important species should also be considered as these species support the food web.
- Particle motion and mitigation are two main discussion topics.
- Uncertainty is important to know! (Expert Judgement).
- What constitutes best practise? – Standards.
- Need to consider limitations of a particular study – i.e. prior exposure of the animal to noise source.
- Extrapolation of results is important – what does the experiment tell you in the real world?
- It was suggested that a way forward may be to hire an expert group to review proposals so reviewers with expertise are evaluating work.
- It was also highlighted that a list of what should be included in a proposal should be project specific. Maybe undertake a risk assessment approach, for example, all studies undertaking seismic work have to include X, Y and Z (suggested table format). A separate table could then be included which lists certain criteria that ALL proposal should contain (tick box format) – table and parameters could be sent to the applicant, allowing them to tick what their proposal will contain.

5 Annex 1 – Workshop Introduction document

Propose methodologies and guidelines on how to evaluate impacts of noise on marine biota

10-11 April 2014, Avenue de Beaulieu 5, 1160 Brussels, (B)

1) Terms of reference
2) Objectives
3) Agenda
4) Workshop layout
5) Conclusions from legislation and literature review
6) List of Attendees and skills for workshop purposes

1) Terms of reference

To organize a workshop for relevant experts (e.g. from industry, geologists, biologists, NGO's, engineers, physicists etc) to:

"Propose methodologies and guidelines on how to evaluate impacts of noise on marine biota, especially to fill in the knowledge gaps identified in the first part of this project."

The first part of the project consisted of:

a) Review existing relevant literature and results from research projects of the last 8 years.
b) Review initiatives and related legislation to mitigate impacts of underwater sound on marine biota in European and non-European (e.g. USA, Australia, Canada) countries.
c) Make an inventory of impacts by animal group (marine mammals, fish etc), related to sound characteristics (impulsive/ambient, sound level, frequency etc) and proposed upper limits for no or insignificant impact (if available). This should include primary effects (i.e. directly from sound wave propagation) and secondary effects, such as cavitation and shockwave formation, that originate from sound waves and can have important consequences.
d) Identify gaps in the current knowledge of impacts and create an inventory of specific additional research needed

2) Objectives

Objective 1: Discuss and propose a roadmap towards defining Good Environmental Status (GES) for underwater noise.

Work on MSFD descriptor 11 on emissions of energy has so far focussed on developing indicators of the spatial and temporal patterns from emissions of two forms of anthropogenic underwater sound. So far no links have been made to the consequential change in status of the marine environment and its biological components. In some jurisdictions, criteria for defining sounds that have adverse effects on biota have been developed, but none have been developed that would provide a status indicator for the ecosystem as a whole, or for assessing the cumulative effects of sound. Work to develop standards to measure underwater sound is still underway.

(1.1) Review progress towards a consensus for standards to measure and describe underwater sound.

(1.2) Review progress in integrating the results of 'field' Controlled Exposure Experiments (CEE) and other sources of information with models describing population and/or ecological effects.

(1.3) Consider the usefulness of thresholds for describing Good Environmental Status.

(1.4) Draft a roadmap (or roadmaps) towards defining GES.

Objective 2: Identify knowledge gaps and define research needs to address the impacts of underwater noise on marine biota.

Funds may exist within the European Union to support research that enables the attainment of GES. Considerable research is in progress (or in later stages of planning) elsewhere. The workshop should aim to inform the European Commission of its views on priority research areas.

(2.1) Prioritize gaps and define research needs to address the achievement of GES, taking account of existing or planned projects.

Objective 3: Provide guidance for important features and considerations that a proposal related to the effects of underwater noise should have when submitted to the EC for funding. This objective will take a lesser priority at the workshop.

It is likely that any proposals relating to underwater noise that are submitted for funding will be assessed partly by non-specialists. There are important features that will be common to most proposals for projects on underwater sound (e.g. calibration, use of standards, testing of models). Guidance will be of use to both those that submit and those that review the proposals.

3) Agenda

10th April: (Day 1)

Morning 1: 09:00 – 09:15: Registration
09:15 – 09:45: Introduction to the Workshop (M.Tasker)
09:45 – 10:15: "Filling knowledge gaps with invertebrates" (M.André)
10:15 – 10:45: "Acoustic effects on fish and data gaps" (M.Halvorsen)
10:45 – 11:15: "Noise impacts on marine mammals—what do we know? What do we need to know?" (C.Erbe)
11:15 – 11:30: *Coffee break*
11:30 – 12:00: "Forecasting the population-level consequences of acoustic disturbance for marine mammals" (J. Harwood)
12:00 – 12:30: "Acoustic Forecasting: Capabilities and Environmental Sensitivities" (K.Heaney)
12:30 – 13:30: *Lunch break*

Afternoon 1: 13:30 – 15:00: Break-out groups
15:00 – 15:15: *Coffee break*
15:15 – 16:30: Break-out groups
16:30 – 18:00: Plenary wrap-up

11th April: (Day 2)

Morning 2: 09:00 – 10:30: Break-out groups
10:30 – 10:45: *Coffee break*
10:45 – 12:30: Break-out groups
12:30 – 13:30: *Lunch break*

Afternoon 2: 13:30 – 15:45: Drafting report
15:45 – 16:00: *Coffee break*

(Plenary) 16:00 – 17:00: Adopting report
17:00 – 17:30: Close meeting

4) Workshop layout

The workshop is co-chaired by J.Fabrizio Borsani (Cefas) and Mark Tasker (JNCC).

It is a 2-day workshop with approximately 30 international experts. Five invited speakers will address specific topics, and two half days will be used to address workshop tasks in break-out groups and the final half day will be devoted to finalizing and adopting a workshop report in a plenary session.

Invited speakers:

Professor Michel André (UPC) michel.andre@upc.edu

"Filling knowledge gaps with invertebrates"

Professor at the Technical University of Catalonia (UPC)

Director of the Laboratory of Applied Bioacoustics (LAB)

Michel André is an Engineer in Biotechnologies graduated from the Institut National des Sciences Appliquées, INSA, Toulouse, France. He holds a Master degree in Biochemistry and Animal Physiology from the Université Paul Sabatier de Toulouse, France. His PhD Dissertation that he defended at the Universidad de Las Palmas de Gran Canaria was on sperm whale acoustics and noise pollution. He was a research assistant at the San Francisco State University, California, an intern scientist at The Marine Mammal Centre, California and an associate professor at the Universidad de Las Palmas de Gran Canaria, Spain. His research involves the development of acoustic technologies for the control of noise pollution in the marine environment, the study of the biological and pathological impact of noise pollution on cetacean acoustic pathways, the mathematical, physical, morpho- and electro-physiological mechanisms of the cetacean bio-sonar as well as the extraction of the information from their acoustic signals.

Dr. Michele Halvorsen (CSA) mhalvorsen@conshelf.com

"Acoustic Effects on Fish and Data Gaps"

Ph.D., Ocean Science and Marine Mammal Observer Business Line Manager, CSA Ocean Sciences Inc

Dr. Halvorsen has 10 years of project/program experience. Dr. Halvorsen's areas of expertise include marine life and biotechnology; environmental acoustic ecology; and effects of intense anthropogenic sounds such as sonar, pile driving, seismic, noise, behavior/neuroethology, fish fitness/physiology, bioacoustics, and acoustic monitoring systems, both active and passive. She has managed field research projects that involved large interdisciplinary teams and has successfully led teams to achieve program goals and deliverables. Dr. Halvorsen was the co-PI and project manager for field studies that examined the effect of the U.S. Navy's low- and mid-frequency sonar on the hearing of several fish species and co-PI for an studies involving pile driving. Dr. Halvorsen has graduate training in neurophysiology of the auditory system of mammals and fish and in neuroethology (i.e., animal behavior). Her current focus is on the effects of anthropogenic sound on the physiology and behavior of fish and marine mammals, and her research has involved barotrauma (tissue damage) response assessment of fish from pile driving, navy sonar, blasting, seismic, and tidal turbine noise. Drs. Halvorsen co-developed a Fish Index of Trauma (FIT) model that maps the exposure sound metrics with the fish's biological responses. This FIT model is applicable to any type of sound exposure (pile driving, explosives, tidal turbine, etc.) and can be used to assess general health conditions. The culmination of results from these projects has positioned Dr. Halvorsen as an expert in the effects of underwater acoustics and effects on fish.

Dr. Christine Erbe (Curtin University Perth) c.erbe@curtin.edu.au

"Noise impacts on marine mammals—what do we know? What do we need to know?"

Christine holds an MSc in physics (University of Dortmund, Germany) and a PhD in geophysics (University of British Columbia, Canada). She has worked in industry (starting as a secretary and book keeper for an IT company, growing into a private consultant and ending as Director of JASCO Australia), in government (underwater noise research & regulation, Fisheries & Oceans Canada), and in high-school education (very briefly), and recently moved back into academia as Director of CMST at Curtin University. Christine's interests are underwater sound (ambient, anthropogenic & biological), sound propagation, signal processing and noise effects on marine fauna. Several times a year, Christine is invited to speak on underwater noise at international symposia. She's a reviewer for 11 scientific journals and several international research grant schemes. She's a member of the Animal Bioacoustics Technical Committee of the Acoustical Society of America, and she's the Australian Government representative on the International Standardization Organization (ISO) working group on standardising underwater noise measurements of vessels.

Professor John Harwood (PCAD, UStAndrews) jh17@st-andrews.ac.uk

"Forecasting the population-level consequences of acoustic disturbance for marine mammals"

John Harwood is Professor of Biology at the University of St Andrews, UK. He was Director of the NERC Sea Mammal Research Unit, which advises the UK and Scottish Governments on the conservation of seals and whales, from 1978-1996, and Director of the Centre for Research into Ecological and Environmental Modelling from 2004-2009. At St Andrews, he helped establish courses on Sustainable Development, Conservation Biology, Biodiversity and Fisheries Management, and he is still active in all these areas. At the moment, his main interest is in developing methods for assessing and mitigating the effects of disturbance on marine ecosystems.

Dr. Kevin Heaney (OASIS) oceansound04@yahoo.com

"Acoustic Forecasting: Capabilities and Environmental Sensitivities"

Dr. Heaney has extensive experience in ocean acoustic propagation and modeling, optimal oceanographic sampling and data-assimilation, geo-acoustic inversion, adaptive sonar signal processing and data analysis. He has worked on a variety of programs, including long-range ocean acoustic tomography, analysis of global scale propagation measurements (including Heard Island and Perth-Bermuda), geo-acoustic inversion and rapid environmental characterization, effects of internal waves on signal coherence, and theoretical optimization of monitoring equipment for hydroacoustic stations of the Comprehensive Test Ban Treaty Organization's International Monitoring System. Dr. Heaney has successfully transitioned algorithms to NAVOCEANO, NAVSEA and CNMOC. Dr. Heaney also has significant experience in adaptive signal processing from both a modeling and an experimental perspective.

Structure of break-out groups:

Three break-out groups of 12-13 participants will be formed. Each break-out group will consider each of the three workshop Objectives, but in order to ensure that reasonable consideration is given to each objective, Break-out group A will start with Objective 1, Break-out group B with Objective 2 and Break-out group C with Objective 3. After some time each break-out group will stop working on the initial Objective and move on to the next one in line.

Approximate timings:

10 April 13:30-15:00

Break-out group A: Objective 1

Break-out group B: Objective 2

Break-out group C: Objective 3

10 April 15:15-16:30

Break-out group A: Objective 2

Break-out group B: Objective 3

Break-out group C: Objective 1

11 April 09:00-12:30

Break-out group A: Objective 3

Break-out group B: Objective 1

Break-out group C: Objective 2

5) Conclusions from legislation and literature review

The only EU legislation to explicitly address underwater noise is the Marine Strategy Framework Directive (2008/56/EC MSFD). This lists "input of energy, including underwater noise is at levels that do not adversely affect the marine environment" as one of the qualitative descriptors that can define Good Environmental Status. In a number of European processes since the adoption of MSFD, ways of better describing and measuring the pressure on the marine environment have been developed collectively. In 2010, the European Commission formally decided (2010/477/EU) that two criteria for determining the pressure on the marine environment should be used by EU Member States. These were Distribution in time and place of loud, low and mid frequency impulsive sounds (11.1) and Continuous low frequency sound (11.2). More detailed descriptions of indicators are associated with both of these Criteria. This workshop forms part of the collective way forward to use these criteria and indicators in the process of defining Good Environmental Status more quantitatively.

A number of other pieces of EU legislation (and nation legislation implementing EU legislation) include underwater sound indirectly in their implementation. These include the Habitats and Species Directive (92/43/EEC), the Environmental Impact Assessment Directive and the Strategic Environmental Assessment Directive. These deal respectively with impacts on protected species and habitats, impacts from individual developments and impacts from industry sectors. Examples of national implementation of these Directives relevant to underwater noise include:

- The UK's seismic survey guidance (JNCC, 2010) that has to be followed as a condition of consent to carry out seismic surveys.
- Germany has defined a dual sound level threshold (160 dB (SEL)/190 dB (SPL peak-to-peak) that must not be exceeded outside a 750 m radius around a pile.

<u>Experimental data availability on the effects of noise on marine biota and most pertinent data gaps</u>

- Considerably more empirical data exist for impacts of anthropogenic noise on marine mammals and fish compared to other taxa, although it should be noted that there is effectively no data to assess possible impacts of particle velocity on fish.
  - ✓ e.g. There is no data on underwater sound detection of diving birds.
  - ✓ e.g. There is very limited data on the sound detection by invertebrates, particularly and very little scientifically robust data on the effects of noise exposure.

- For all taxa, there is an apparent lack of data on chronic effects of noise exposure, as well as population and ecosystem effects.
  - ✓ e.g. there is practically no information on chronic effects of noise on marine receptors.
  - ✓ e.g. the biological significance of acoustic impacts is poorly understood (e.g. critical behaviour such as mating and nursing may be repeatedly disrupted, affecting survival of the population).
  - ✓ e.g. the ranking of noise among environmental stressors (e.g. culling, ship strikes, pollution, prey overfishing, climate change, habitat degradation etc.) on marine receptors and the interactions of stressors are not understood.
  - ✓ e.g. the manner in which repeated exposure gets accumulated by the animal and the effects of cumulative exposure are unknown. Regulation and mitigation mostly address acute exposure from a single operation or event and direct damage.
  - ✓ i.e. studies on the chronic effects of noise on development and animal behaviour.

- There is a general scarcity of empirical data integration with population/ecological modelling.

- Data coverage with respect to sample size (e.g. number of individuals and species) and exposure context (e.g. behavioural and natural history of the receptor, sound source type, acoustic habitat) is generally low.

- Overall, only small numbers of studies have considered controlled exposure experiments in the presence of a real sound source to study either the physiological effects of noise or the behaviour of the animals under exposure. To date, controlled exposure data for real sources in the wild are also extremely limited.
  - ✓ e.g. CEE on fish in controlled natural or semi-natural environment (e.g. mesocosm), considering both acoustic pressure and particle velocity components of the sound field, appropriate innovative experimental setups and methods (e.g. by combining tagging, remote sensing, etc.).
  - ✓ e.g. there is a need for more comprehensive studies regarding the potential for specific sound sources to effect local sensitive biota (e.g. crustaceans and seismic air gun noise; impact piling noise and marine mammals).

Table 1 was compiled to help identify (i) knowledge gaps and (ii) research data requirements with regard to the current understanding of the potential impacts of underwater noise on individuals, populations and ecosystems.

Our understanding of the extent of current knowledge is presented for various taxa and specific consideration is given to fish larvae. In general, consideration was given to marine receptors that are i) commercially important, ii) protected by legislation and/or iii) thought or shown to be sensitive to underwater sound.

The extent of available published empirical data is indicated by colour, where green is intended to indicate existence of a very comprehensive evidence data base and thus extensive understanding of the impacts of noise, amber depicts *some* data availability and red shows areas where there is a general lack of robust empirical data and hence very limited understanding of the potential noise impacts.

This compilation looks to provide an overview of the present knowledge, and would be expected to evolve as new empirical evidence becomes available.

Table 1: Overview of knowledge gaps relating to impacts of noise on sensitive marine organisms, their populations and ecosystems.

Knowledge gaps relating to underwater noise impact on marine biota		Vertebrates					Invertebrates		
		Marine mammals	Fish	Fish Larvae	Sea turtles	Birds	Crustaceans	Cephalopods	Bivalve/ Bivalve larvae
Detection of	acoustic pressure					(No data)			
	particle motion								
Injury to organs for sound field detection	acoustic pressure			*					*
	particle motion			*					*
Behavioural response to noise	acoustic pressure								
	particle motion								
Chronic effects of noise exposure									
Population effects of acoustic disturbance									
Resulting effects on ecosystems									

*Relates to injury to larvae *per se*

Legend

	Considerable understanding/ Limited requirement for further research (focused research may be required in some areas)
	Some knowledge (Little to Fair)/ Further research required – knowledge gaps remain

	Very little understanding or published work/ Requirement for further research

6) List of Attendees

(Two delegates were unable to attend at a short notice. They are indicated by *)

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