INTERNATIONAL REGULATION OF UNDERWATER NOISE

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Underwater noise is a by-product of marine industrial operations, that plays an increasing role in environmental impact assessments. It can have a variety of temporary to chronic bioacoustic impacts on marine fauna, such as behaviour modification, changes in habitat usage or migration, communication masking, and auditory and non-auditory physiological impacts. There are still lots of unknowns. Audiograms (curves of hearing sensitivity) have only been measured of few individuals of about 20 marine mammal species, and even fewer individuals and species of other marine genera. No audiograms exist for sperm whales or baleen whales. Behavioural responses likely depend on prior experience (habituation versus sensitisation), age, gender, health, context, current behavioural state etc., but we don't understand the details or mechanisms. Data on hearing loss and acoustic trauma is even scarcer. Finally, what is the biological significance of individual acoustic impacts? Environmental agencies and regulators struggle for data to support environmental management. Research on the impacts of underwater noise is being undertaken around the globe, but there is a substantial delay in publication and science transfer. In the face of uncertainty, what is being done? This article aims to provide a brief overview of underwater noise regulation in Australia and overseas. Regulations vary from country to country. Some jurisdictions use specific do-not-exceed thresholds, which are very broadly applied across differing species and environments, and sound sources. Others use more conceptual requirements such as 'minimising impact to acceptable levels', yet what this means has to be defined and demonstrated by each proponent for their specific situation (i.e., operation, environment and organisms). Furthermore, in many situations, multiple differing Acts and policies apply.

INTRODUCTION

The ocean is not a quiet place. It is naturally noisy with sounds from physical (wind, waves, rain, ice) and biological sources (whales, dolphins, fish, crustaceans etc.). Anthropogenic contribution to underwater noise has increased rapidly in the past century. In some parts of the world, low-frequency ambient noise has increased by 3.3 dB between 1950 and 2007, which was attributed to commercial shipping [1].

As ocean water conducts light very poorly but sound very well, many marine animals have evolved to rely primarily on their auditory system for orientation, communication, foraging and sensing their environment. For example, humpback whales (*Megaptera novaeangliae*) sing songs for hours to days. Killer whale (*Orcinus orca*) pods sharing the same geographic habitat have different dialects, and can be told apart from their calls. Odontocetes (toothed whales) use echolocation (active sonar) to navigate and forage. Fish and shrimp sing evening choruses. Coral larvae tune in to reef sounds for homing purposes.

Underwater noise can interfere with all of these functions on an individual yet ultimately population level. The effects of noise and the ranges over which they happen depend on the acoustic characteristics of the noise (level, spectral distribution, duration, duty cycle etc.), the sound propagation environment, and the characteristics of the acoustic receptor (the animal). Figure 1 shows a sketch of the potential zones of impact. These types of impact have been demonstrated in species of marine mammal and fish. As sound spreads through the ocean away from its source, the sound level decreases. At the longest ranges, a sound might barely be detectable. For behavioural responses to occur, a sound would mostly have to be significantly above ambient levels and the animal's audiogram. However, avoidance at tens of km has been reported that was estimated to be at the limit of audibility in beluga whales (*Delphinapterus leucas*) [2].

Figure 1. Potential zones of bioacoustic impact around a noise source (red star).With increasing distance from the source, the impacts might include permanent or temporary hearing loss, communication masking and alterations of behaviour. All of these effects, including mere audibility, could induce stress.

Noise can mask communication, echolocation and the sounds of predators, prey and the environment. Masking

depends on the spectral and temporal characteristics of signal and noise [3]. The potential for masking can be reduced due to an animal's frequency and temporal discrimination ability, directional hearing, co-modulation masking release (if noise is amplitude modulated over a number of frequency bands) and multiple looks (if the noise has gaps or the signal is repetitive) [4], as well as anti-masking strategies (increasing call level, shifting frequency, repetition).

Auditory threshold shifts (hearing loss) can be either temporary (TTS) or permanent (PTS). Marine mammal TTS data have formed the basis for regulation of impulsive sounds in Germany [5] and the USA [6]. Noise—under certain circumstances—can affect non-auditory systems including the vestibular and nervous systems, can cause physical damage to tissues and organs, and can lead to concussion, cavitation, and stress. Pro-longed stress can cause health problems. Many of the discussed effects might be related, e.g. TTS affects audibility of a signal and thus alters the normal behavioural response of an animal. Or, noise received by a diving animal might induce stress leading to a flight response involving rapid surfacing that can cause decompression sickness or injury. How do temporary and individual impacts relate to population impacts? The Population Consequences of Acoustic Disturbance (PCAD) and Population Consequences of Disturbance (PCOD) models try to link noise characteristics to population effects [7]. While cumulative exposures from multiple sources over large geographic scales and long durations can be modelled fairly easily and reliably [8-10], we do not yet understand how acoustic exposures integrate in terms of impact. And finally, acoustic stressors can "add" synergistically to non-acoustic stressors such as light, chemical pollution, food depletion etc.

Given that data on bioacoustic impact is mostly limited to short-term individual responses, management of underwater noise is focussed on specific events limited in space and time. An animal, however, would experience multiple separate events along its migration, for example. A more holistic approach is needed, but complicated by a lack of information on cumulative impacts, the impracticability of managing multiple events separated in space and time, and the involvement of multiple jurisdictions.

Low-frequency (< 100 Hz) sound, in particular, can cross entire ocean basins. Noise that originates in one country or jurisdiction travels into neighbouring jurisdictions, making its regulation an international affair. Ocean noise can legally be treated as a "transboundary pollutant" [11] - "transboundary" because it crosses boundaries between jurisdictions, and "pollutant", because it fits the United Nations Convention on the Law of the Sea (UNCLOS) definition of marine pollution, which can be a substance or energy released into the marine environment, and which may result in deleterious effects on marine life [12]. UNCLOS has been signed by 138 countries. A framework for a holistic approach to the management of underwater noise is established by some international agreements—specifically within Europe.

INTERNATIONAL AGREEMENTS

The most widely signed agreements relating to underwater noise are discussed below.

Marine Strategy Framework Directive (MSFD)

The MSDF [13] is a European initiative that considers a multitude of anthropogenic "stressors" and their potentially cumulative effects. Member States are requested to develop an ecosystem-based approach to the management of human activities, enabling a sustainable use of marine goods and services. The objective is to achieve and maintain "good environmental status" by 2020, measured by 11 descriptors, the 11th of which refers to underwater noise: "The introduction of energy, including underwater noise, must be at levels that do not adversely affect the marine environment." [14].

Three indicators for descriptor 11 were suggested in 2010, requiring 1) the registration of low- and mid-frequency (10 Hz – 10 kHz) impulsive sounds exceeding either a sound exposure level (SEL) of 183 dB re 1 μPa^2s @ 1m or a peak pressure level (SPLpk) of 224 dB re 1 µPa @ 1m, as well as the spatial and temporal distribution of such events; 2) the tracking and possibly limitation of the number of vessels equipped with sonar systems (50 - 200 kHz) in order to reduce potential impact on high-frequency cetaceans inhabiting coastal waters in the EU; and 3) the monitoring of continuous low-frequency sound with the aim of keeping the annual average ambient noise level in the 1/3 octave bands centred at 63 Hz and 125 Hz, as measured by a statistical representative set of observation stations, below the baseline values of the year 2012 or 100 dB re 1 µPa root-mean-square (rms). Noise mapping (through measurement and modelling) was further suggested to analyse noise budgets. A low-frequency level of <100 dB re 1 µPa rms is very ambitious and not achievable in areas of busy commercial shipping as demonstrated by Erbe et al.'s cumulative ship noise model [9]. The original indicators were refined in 2012 [15] requiring member states to register any impulsive events that "are likely to entail significant impact on marine animals", in terms of both SEL and SPLpk, and to monitor trends in ambient noise in two 1/3 octave bands centred at 63 and 125 Hz. All target levels were removed, as was the suggestion to register sonar systems.

HELCOM

The Helsinki Commission (HELCOM) aims to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation involving Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden and the European Community. Project CORESET (2010-2013) is developing a set of core indicators to assess the effectiveness of the implementation of the Baltic Sea Action Plan and the above-mentioned MSDF. One indicator will relate to underwater noise and impacts on marine mammals and likely involve mapping of anthropogenic sound sources and modelling of cumulative noise levels. Under the LIFE+ Environment Policy & Governance programme, the European Commission is currently funding the Baltic Sea Information on the Acoustic Soundscape (BIAS) project to establish and implement standards and tools for the management of underwater noise, in accordance with the MSFD. Soundscape maps will be produced as part of a GIS-based planning tool, initially showing the underwater noise generated by commercial vessels and allowing the modelling of noise footprints of intermittent operations (e.g. pile driving

and underwater explosions). Standards will be developed for hardware sensors and data, as well as data recording and processing.

OSPAR Convention

OSPAR guides international cooperation on the protection of the marine environment of the northeast Atlantic. The OSPAR Commission includes 15 European countries and the European Commission, representing the European Union. The Commission recently reviewed the potential effects of man-made underwater sound on marine life and concluded that there was not enough scientific information to evaluate the effectiveness and adequacy of current measures for the protection of marine life, and called for more research on animal audition, behaviour and distribution, as well as man-made noise characteristics, distribution and budgets, and mitigation. A lack of standardisation of environmental impact assessments was noted [16]. Following suite to conclusions of the Quality Status Report 2010 and the Environmental Impact of Human Activities Committee, a drafting group under the lead of Germany and the UK is currently developing a proposal for OSPAR guidance on the environmental impacts of underwater noise and mitigation measures.

ASCOBANS

The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) was signed by eight countries bordering the Baltic and North Seas and focused on bycatch rates, habitat deterioration and anthropogenic disturbances to small cetaceans [17]. ASCOBANS specifically requires that all parties address underwater noise. Regarding seismic surveys, operators are asked to time surveys outside of marine mammal presence, to reduce noise levels as much as possible, to monitor marine mammal presence, and to ensure no marine mammals are within short-range exclusion zones when operations commence. With regards to pile driving, operators are additionally asked to employ technical measures for sound absorption, and to employ measures for alerting marine mammals to the onset of pile driving (e.g., acoustic deterrence devices) [18].

ACCOBAMS

The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) was signed by eight countries bordering these waters. While ACCOBAMS calls for research and monitoring, few explicit recommendations on noise mitigation have been released, apart from reductions in vessel speed, maintenance of propellers, timing of operations when marine mammals are less present, and noise reduction mechanisms [19].

International Convention on Migratory Species

116 countries, including Australia, signed this Convention. The draft resolution on adverse anthropogenic marine/ocean noise impacts on cetaceans and other biota (UNEP/CMS/Res.9.19/Rev.3/5 December 2008) urges Parties to undertake environmental assessments of underwater noise, adopt mitigation measures and develop guidelines by monitoring of ambient noise, studying the sources of noise, compiling a reference noise signature database, characterising sound propagation, studying bioacoustic impacts, and investigating the benefits of noise protection areas.

There is no shortage of international agreements, in particular within Europe, intending to protect marine ecosystems and recognising noise as an environmental stressor. However, there is no international agreement on the methods for protection. Guidelines and regulations are up to individual countries. Explicit guidelines have only been issued for certain operations, mostly pile driving and seismic surveying (both impulsive sound sources), primarily with regards to impacts on marine mammals—mostly cetaceans [20,21].

COUNTRY-SPECIFIC GUIDELINES

The following paragraphs provide examples of underwater noise regulation in countries with a more stringent approach. While specific requirements differ from country to country, the general approaches are similar and may involve:

The Source

- Source selection: Some countries stipulate that a (seismic) source with minimal practical power be used, or that alternative foundation techniques be used instead of pile driving of offshore wind-turbines.

Location & Timing

- Time/area closures: These are mostly applied to seismic surveys during seasons of whale breeding and calving in habitats with significant animal presence.

Operational Parameters

- Soft-start/ramp-up: Seismic surveys or pile driving are required to start at a low acoustic power, ramping up to full power over 20-40 minutes. The idea is to send a warning to animals allowing them to desert the area. There are currently no scientific results validating this concept. The Behavioral Responses of Australian Humpback Whales to Seismic Surveys (BRAHSS) study funded by the Oil and Gas Producers' (OGP) Joint Industry Program (JIP) is currently investigating the effectiveness of soft-starts.
- Use of vibratory pile driving instead of or at the beginning of impact pile driving.

Mitigation Equipment

- Bubble screens: Almost all European countries require bubble curtains to absorb and scatter some of the energy from impact pile driving.

Mitigation Procedures

- Safety zones: Real-time mitigation methods are implemented within a zone (radius) around the pile driving or seismic source. These could be shut-down zones close to the source, low-power zones at longer radii and mere observation zones at the longest radii.
- Marine mammal observers (MMO): Dedicated visual observers are required to monitor safety zones for animal presence.
- Pre-shoot survey: For commonly 30 minutes prior to operations, the observation zone is surveyed for marine animal presence. If none are detected during this time, operations can commence.

- Low-power and shut-down: If animals enter the corresponding zones, operations have to switch to low power or shut down. Operations can recommence once animals have left, and (depending on country) after an additional pre-shoot survey and/or soft-start.
- Passive acoustic monitoring (PAM): In addition to MMOs, PAM is recommended specifically for operations in poor visibility.

United Kingdom

The Joint Nature Conservation Committee (JNCC) released a pile driving protocol for minimising the risk of injury to marine mammals [22], and similar guidelines for seismic surveys [23]. The developer must determine what species are present when, and consider seasonal timing. The Best Available Technique (BAT) has to be employed within the constraints of commercial affordability and practicality. Hammer modifications, sleeving or muffling, as well as vibratory and gravity-based piling instead of percussive piling, might be necessary. Simultaneous visual and passive acoustic monitoring (PAM) is suggested during operations. There are requirements for marine mammal observer (MMO) and PAM operators' training and work schedules, location (viewing platform) and equipment. The size of the monitoring and mitigation zones is established during the environmental impact assessment and agreed with the regulator and is no less than 500 m, see Figure 2a. Piling should not be commenced during darkness or poor visibility (*e.g.*, fog or Sea State > 4). MMOs and/or PAM operators should monitor the mitigation zone for at least 30 minutes prior to piling. Piling should not begin if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection. A soft-start (i.e., gradual ramping up of piling power) period of at least 20 minutes is recommended. If an animal enters the mitigation zone during soft-start, the power should not be increased until the animal exists and remains outside of the zone for 20 minutes. Acoustic deterrent devices (ADDs) may be utilised if the effectiveness of candidate devices on the key marine mammal species can be demonstrated during the environmental impact assessment process.

After the end of the piling activity, a written report should be sent to the regulator including completed marine mammal reporting forms; date and location of the piling operations; a record of all occasions when piling occurred, including details of the duration of the pre-piling search and soft-start procedures, and any occasions when piling activity was delayed or stopped due to presence of marine mammals; details of watches made for marine mammals, including details of any sightings, details of the PAM equipment and detections, and details of the piling activity during the watches; details of any acoustic deterrent devices used, and any relevant observations on their efficacy; details of any problems encountered during the piling process including instances of non-compliance with the agreed piling protocol; and any recommendations for amendment of the protocol.

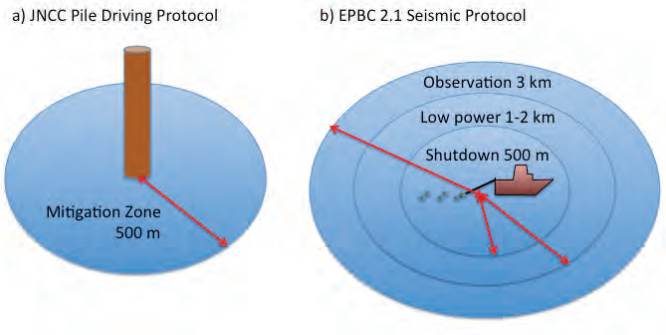

Figure 2. a) The mitigation radius, measured from the pile location, must not be less than 500 m [22]; b) Precaution zones surrounding the seismic airgun source (Australian EPBC Act Policy Statement 2.1).

Germany

The German Federal Government requires an exclusion zone of 750 m from pile driving for marine mammals. Measures must be employed by the operator to keep the received level at 750 m below a sound exposure value of 160 dB re 1 μPa^2s and below a peak-to-peak sound pressure value of 190 dB re 1 µPa [24]. These levels were based on TTS measurements in a harbour porpoise after exposure to single impulsive signals [5], and were rounded down to allow for cumulative effects and intra-species variability. While this exclusion zone is intended to avoid TTS, behavioural effects are acknowledged to be likely. Temporal and spatial restrictions are additionally considered in critical habitats during seasons of high animal abundance.

United States of America

The Endangered Species Act (ESA) protects endangered species across the classes (including marine mammals). The National Marine Sanctuaries Act protects marine environments with special national significance based on conservation, recreational, ecological, historical, scientific, cultural, archaeological, educational or aesthetic qualities. The Marine Mammal Protection Act (MMPA) specifically protects marine mammals from anthropogenic noise. It is administered by the National Marine Fisheries Service (NMFS) and the Fish and Wildlife Service. The latter has jurisdiction over species such as manatees, polar bears, walrus and sea otters. NMFS has taken the more active role in issues related to underwater noise.

The MMPA defines 'take' as harassment, hunting, capture, killing or collection - or the attempt thereof. Under the 1994 Amendments to the MMPA, harassment is defined as any act of pursuit, torment or annoyance, that has the potential to injure (Level A Harassment) or to disturb (Level B Harassment) a marine mammal or stock in the wild. Level B Harassment includes the disruption of behavioural patterns, e.g. migration, breathing, nursing, breeding, feeding, or sheltering. Authorisation for incidental 'takings' may be granted by NMFS if the taking will have a 'negligible' impact on the animal populations, i.e. not affect annual rates of recruitment or survival. Notices of a proposed Incidental Harassment Authorization (IHA) are published by NMFS and public comments are considered in developing, if appropriate, IHAs.

NMFS' policy for pulsed sound is currently under review and requires that cetaceans and pinnipeds not be exposed to SPLrms > 180 and 190 dB re 1 μPa respectively [25], to prevent Level A Harassment. The threshold for Level B Harassment from pulsed sound is generally set at 160 dB re 1 μPa rms.

As an example, in 2008, the Port of Anchorage applied for and was granted an IHA to take, by Level B Harassment, up to 34 beluga whales (*Delphinapterus leucas*), 20 harbour seals (*Phoca vitulina*), 20 harbour porpoises (*Phocoena phocoena*), and 20 killer whales (*Orcinus orca*) during port expansion [26]. Level B Harassment was expected to consist of short-term, mild to moderate behavioural (altered headings, fast swimming changes in dive, surfacing, respiration and feeding patterns, and changes in vocalisations) and physiological responses (stress). Under the IHA, three years of sighting data around the Port had to be collected prior to construction yielding information on animal abundance, group size, group composition, and behaviour, from which expected monthly takes were calculated. Bubble curtains were considered for mitigation, however, due to strong currents were determined impractical. NMFS required that construction activities be scheduled during low presence of beluga whales. Pile driving was not to occur within two hours before and after low tide, as animal presence peaked during low tide. Through modelling and *in situ* transmission loss measurements, ranges to 160 dB re 1 μPa rms (Level B Harassment from percussive pile driving) and to 120 dB re 1 μPa rms (Level B Harassment from vibratory piling) were determined. NMFS imposed a 200 m shut-down zone for any single animal, and a 350 m shut-down zone for more than five beluga whales in a group or calves.

Piles had to be driven with a vibratory hammer to the maximum depth possible before switching to impact pile driving. A soft-start was employed: For vibratory piling, this meant 15 s at reduced energy followed by a 1-minute break, three times in a row. For impact pile driving, this meant three strikes at 40% energy followed by a 1-minute rest, then two subsequent three-strike sets. If an animal moved into the 200 m safety zone during the soft-start procedure, pile driving had to be delayed until the animal had left the zone or until it was not resighted within 15 minutes. The safety zone was monitored by trained observers 30 minutes prior to and during pile driving. Additional land-based MMOs recorded beluga behavioural responses to construction activities. Pile driving was not to occur if weather conditions prohibited adequate monitoring of the 200 m safety zone. Passive acoustic detection was required for validation of visual data and for monitoring noise exposures to be correlated with behavioural responses. For in-water heavy machinery operations other than pile driving (hydraulic excavators, clamshell equipment used to place or remove material, dump-scows, barges and tugs), if a marine mammal came within 50 m, operations would cease and vessels would slow down while still maintaining control of the vessel and safe working conditions. If the maximum authorised take was reached, any beluga entering into the Level B Harassment isopleth would trigger mandatory shut-down. Weekly monitoring reports had to be submitted to NMFS.

New Zealand

New Zealand does not have any policies for underwater noise exposure of marine fauna yet. A Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations was published in 2012 [27], and will be subject to an implementation performance review in 2015, prior to further consideration of mandatory regulations. The current code is neither legally binding nor enforceable. In general, marine seismic surveys should not happen in sensitive, ecologically important areas during key biological periods where species of concern are breeding, calving, resting, feeding or migrating. The lowest practicable power level for the seismic source should be used. The code considers three levels of seismic surveys. The Director-General must be notified of Level 1 & 2 surveys at least three months in advance. The proponent must prepare a Marine Mammal Impact Assessment (MMIA), describing the proposed activities, identifying all potential effects on marine species and habitats, and detailing an impact mitigation plan to reduce impacts to acceptable levels. Expert technical advice should be sought. While there is no formal approval process resulting in a consent, the Director-General will advise if the MMIA suffices or needs further mitigation measures. Where activities are planned in Areas of Ecological Importance or Marine Mammal Sanctuaries, sound propagation modelling must be included in the MMIA and ground-truthed during the course of the survey. If sound levels are predicted to exceed either 171 dB re 1 μPa^2s within the following mitigation zones for Species of Concern or 186 dB re 1 μPa^2s at 200 m, the mitigation zone might be extended. In addition:

1. Level 1 (source > 427 in^3): minimum of 2 MMOs and 2 PAM operators present at all times; pre-operation MMO and PAM survey of 30 minutes over mitigation zone; 20-40 minute soft-start; 1.5 km shut-down zone for Species of Concern with calves; 1 km shut-down zone for Species of Concern without calves; delayed start if Other Marine Mammal within 200 m
2. Level 2 (source 151-426 in^3): minimum of 2 MMOs present at all times; PAM optional; pre-operation MMO survey of 30 minutes over mitigation zone; 20-40 min soft-start; 1 km shut-down zone for Species of Concern with calves; 600 m shut-down zone for Species of Concern without calves; delayed start if Other Marine Mammal within 200 m
3. Level 3 (source < 150 in^3, sparkers, pingers, boomers): no specific mitigation zones

Requirements for minimum training and experience, and on-duty shift duration for both MMO and PAM observers exist. A written report on sightings must be submitted to the Director-General within two months after completion of the survey. While the code explicitly treats marine mammals, operators are strongly encouraged to consider and mitigate impacts on other key species (*e.g.* turtles, penguins, seabirds). Guidelines for borehole seismic surveys are similar depending on the acoustic source. The use of explosives is prohibited in New Zealand continental waters.

Australia

The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) came into effect on 1.1.2012 and is responsible for monitoring and enforcing compliance with the Offshore Petroleum and Greenhouse Gas Storage Act 2006 and (Environment) Regulations 2009 in Commonwealth waters. The Environment Regulations require that petroleum activities in Commonwealth waters be carried out in a manner consistent with the principles of ecologically sustainable development and in accordance with an accepted environment plan (EP). The operator must develop an EP for assessment and acceptance by NOPSEMA prior to operations [28]. The intent of the EP is to act not only as a regulatory compliance document, but also as a practical implementation and management tool to be used by operators in the field. The EP will describe the operations in enough detail to determine potential environmental risks and impacts. The EP will further describe the natural physical and biological environment, including any environmental receptors that may be affected by the proposed operations (both planned and unplanned), and spatiotemporal sensitivities (e.g. breeding and nesting seasons and habitats, animal migrations, spawning events). Consultations with stakeholders (people or organisations whose functions and interests may be affected by the operations) are required by the Regulations, might include workshops and should be ongoing. An operator may need to complete relevant studies to support the assessment and ongoing management of environmental impacts (literature reviews, biological surveys, modelling, specialist consultation etc.). The EP must establish management measures and demonstrate that any environmental risks and impacts are as low as reasonably practicable (ALARP) and at an acceptable level. Where uncertainty about impacts and likelihood exists, a precautionary approach should be adopted. The EP must have environmental performance objectives outlining the environmental goals of the operator, environmental performance standards stating the level of performance required of control measures, and measurement criteria that allow operators to measure if the objectives and standards were met during operations. The EP must include an implementation strategy and monitoring, recording and reporting arrangements that allow NOPSEMA to determine if the objectives and standards were met. Once NOPSEMA has accepted an EP, the operator must submit a summary for publication on the NOPSEMA website[1], where many examples of accepted EPs for various operations emitting underwater noise can be found.

Different from many other jurisdictions, these regulations do not prescribe a specific approach to environmental risk reduction (e.g. acoustic exposure thresholds); rather, operators are encouraged be flexible in their approach and employ innovative measures that are tailored to their specific circumstances. These regulations recognise that every situation (local environment, organisms, operations) is different and that no single approach (threshold or minimum standard) suits all situations and that what is "reasonably practicable" changes over time as technology, expertise and our understanding of environmental impacts evolve.

While NOPSEMA is responsible for Commonwealth waters, States and Territories are responsible for managing the marine environment within 3 nautical miles from the coast. An example of a mitigation and monitoring program to protect dolphins from pile driving impacts in State waters is given in [29].

Under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999, the onus is on the operator to decide whether a proposal is likely to have an impact on a matter of national environmental significance and also needs to be referred to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) for assessment and decision. The EPBC Act Policy Statement 2.1 (2008), published by SEWPaC (formerly DEWHA), provides standards and a framework designed to minimise the risk of acoustic impacts to whales (baleen whales and large toothed whales) from marine seismic operations. Seismic surveys should be planned outside of whale breeding, calving, resting or feeding habitats and times. Thirty-minute pre-operation visual observation, 30-minute soft-start, start-up delay if whales are sighted within the low-power zone, ongoing visual observation during operations, and power-down or shut-down if a whale is sighted within the low-power or shut-down zone are required irrespective of location and time of year of survey. Passive acoustic monitoring is recommended in addition to visual observation, specifically during low visibility. This policy statement requires the computation of the SEL from single emissions at 1 km range. If SEL > 160 dB re 1 μPa^2s for 95% of the time, an observation zone of 3 km, a low-power zone of 2 km and a shut-down zone of 500 m are imposed (Figure 2b). Else, these zones are 3 km, 1 km and 500 m respectively. Time/area closures are imposed in the Great Australian Bight during winter (right whale breeding & calving). The requirements of the policy are often applied as Conditions of Approval by SEWPaC on seismic and other petroleum activities. There are no policy statements for smaller dolphins and porpoises; and none for sources other than seismic airguns.

DISCUSSION

Regulation and enforcement are handled differently from country to country. In fact, even within the same country, different states or jurisdictions regulate noise differently. Political boundaries are meaningless to animals; migratory species experience sequential exposures, and impacts might "accumulate". The United Nations Environmental Programme called for an international approach to research and regulation of anthropogenic noise effects on marine mammals as early as 1985 [30]. The International Maritime Organization (IMO) urged the "development of globally uniform regulations rather than a proliferation of diverse regional or local standards" [31]. There are regional directives involving multiple countries, in particular in the European Union, providing a framework for potentially more "holistic" management. Most of these

[1] http://www.nopsema.gov.au/environmental-management/environment-plans/environment-plan-summaries/

directives stipulate that marine ecosystems must be protected, but do not specify how, and often conclude in a call for further investigation. It is up to each country to interpret and act upon these directives, leaving us with disjoint and disparate management.

Tangible guidelines based on sound science, and effective measures by which noise impact can be mitigated would help, but are still lacking. This is partly because scientific research is still needed on biological impacts and the significance thereof, and partly because of a lack of standards in underwater noise measurement, analysis and reporting. Also, one number is not going to fit all situations (i.e., populations, environments and operations). Rather, guidelines would have to be multivariate and allow for different measures in different circumstances. A large amount of data is needed to tailor guidelines. Based on the author's experience with offshore petroleum projects, the number of, the size of and hence the cost of environmental impact assessments seems to be steadily increasing, yet without an apparent increase in quality or effectiveness. Humungous amounts of data are often collected in these environmental noise monitoring and impact mitigation programs, but do not flow into the public domain and hence do not advance our understanding—a loss to both science and the environment.

REFERENCES

[1] G. Frisk, "Noiseonomics: The relationship between ambient noise levels in the sea and global economic trends", *Scientific Reports* **2**, 437 (2012)

[2] C. Erbe and D.M. Farmer, "Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea", *Journal of the Acoustical Society of America* **108**(3), 1332-1340 (2000)

[3] C. Erbe and D.M. Farmer, "Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise", *Deep-Sea Research Part II* **45**(7), 1373-1388 (1998)

[4] C. Erbe, "Critical ratios of beluga whales (Delphinapterus leucas) and masked signal duration", *Journal of the Acoustical Society of America* **124**(4), 2216-2223 (2008)

[5] K. Lucke, U. Siebert, P.A. Lepper and M.-A. Blanchet, "Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli", *Journal of the Acoustical Society of America* **125**(6), 4060-4070 (2009)

[6] B.L. Southall, A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R.J. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack, "Marine mammal noise exposure criteria: Initial scientific recommendations", *Aquatic Mammals* **33**(4), 411-521 (2007)

[7] National Research Council, *Marine Mammal Populations and Ocean Noise: Determining when noise causes biologically significant effects*, National Academies Press, Washington, 2005

[8] C. Erbe and A.R. King, "Modeling cumulative sound exposure around marine seismic surveys", *Journal of the Acoustical Society of America* **125**(4), 2443-2451 (2009)

[9] C. Erbe, A.O. MacGillivray and R. Williams, "Mapping cumulative noise from shipping to inform marine spatial planning", *Journal of the Acoustical Society of America* **132**(5), EL 423-428 (2012)

[10] C. Erbe, "Modeling cumulative sound exposure over large areas, multiple sources, and long durations", in: A.N. Popper, A.D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology 730*, Springer Verlag, New York, 2012, pp. 477-479

[11] E. McCarthy, *International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution*, Kluwer Academic Publishers, Boston, 2004

[12] United Nations Division for Ocean Affairs and the Law of the Sea, *United Nations Convention on the Law of the Sea (UNCLOS)*, 1982

[13] European Parliament, "Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for communicity action in the field of marine environmental policy (Marine Strategy Framework Directive)", *Official Journal of the European Union* **L 164**, 19-40 (2008)

[14] M.L. Tasker, M. Amundin, M. Andre, A.D. Hawkins, W. Lang, T. Merck, A. Scholik-Schlomer, J. Teilman, F. Thomsen, S. Werner and M. Zakharia, *Marine Strategy Framework Directive*: Task Group 11 Report: Underwater noise and other forms of energy, JRC Scientific and Technical Report No. EUR 24341 EN - 2010, European Commission and International Council for the Exploration of the Sea, Luxembourg, 2010

[15] A.J. van der Graaf, M.A. Ainslie, M. Andre, K. Brensing, J. Dalen, R.P.A. Dekeling, S. M. Robinson, M.L. Tasker, F. Thomsen and S. Werner, *European Marine Strategy Framework Directive - Good Environmental Status (MSFD GES)*: Report of the Technical Subgroup on Underwater noise and other forms of energy, JRC Scientific and Technical Report, TSG Noise & Milieu Ltd., Brussels, 2012

[16] OSPAR Commission, *Overview of the impacts of anthropogenic underwater sound in the marine environment*, OSPAR Report No. 441, London, UK, 2009

[17] Marine Mammal Commission, *The marine mammal commission compendium of selected treaties, international agreements, and other relevant documents on marine resources, wildlife, and the environment: Agreement on the conservation of small cetaceans of the Baltic and North Seas (1992)*, Washington, DC, 1994

[18] ASCOBANS Secretariat, *Adverse effects of underwater noise on marine mammals during offshore construction activities for renewable energy production*, Resolution No. 2, Bonn, Germany, 2009

[19] G.N. di Sciara, *Cetaceans of the Mediterranean and Black Seas: State of knowledge and conservation strategies*, Report to the ACCOBAMS Secretariat, Monaco, 2002

[20] C.R. Weir and S.J. Dolman, "Comparative review of the Regional Marine Mammal Mitigation Guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard", *Journal of International Wildlife Law & Policy* **10**, 1-27 (2007)

[21] R. Compton, L. Goodwin, R. Handy and V. Abbott, "A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys", *Marine Policy* **32**(3), 255-262 (2008)

[22] Joint Nature Conservation Committee (JNCC), *Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise*, Aberdeen, UK, 2010

[23] Joint Nature Conservation Committee (JNCC), *Guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys*, Joint Nature Conservation Committee, Aberdeen, UK, 2010

[24] S. Werner, Towards a precautionary approach for regulation of noise introduction in the marine environment from pile driving, Federal Environment Agency, Stralsund, (2010)

[25] National Marine Fisheries Service (NMFS), *Environmental Assessment on the effects of controlled exposure of sound on the behaviour of various species of marine mammals*, Silver Spring, Maryland, USA, 2000
[26] National Marine Fisheries Service (NMFS), "Small Takes of Marine Mammals Incidental to Specified Activities; Port of Anchorage Marine Terminal Redevelopment Project, Anchorage, Alaska", *Federal Register* **73**(139), 41318-41330 (2008)
[27] New Zealand Department of Conservation, *Code of conduct for minimising acoustic distrubance to marine mammals from seismic survey operations*, Department of Conservation, Wellington, New Zealand, 2012
[28] National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA), *Environment Plan Preparation*, Guidance Note No. N-04700-GL0931 Rev. 0, NOPSEMA, 2012
[29] C. Erbe, "Underwater noise from pile driving in Moreton Bay, Qld", *Acoustics Australia* **37**(3), 87-92 (2009)
[30] United Nations Environmental Programme, Marine Mammals: Global Plan of Action , *UNEP Regional Seas Reports and Studies* **55** (1985)
[31] International Maritime Organization, *International Maritime Organization Resolution* A.927(22), 2001

THEME

ACOUSTICS 2013, the annual conference of the Australian Acoustical Society, will be held in Victor Harbor, South Australia, at the McCracken Country Club, from 17-20 November 2013.

With its theme of Science, Technology and Amenity, Acoustics 2013 Victor Harbor will include plenary sessions addressing the impact of science and technology on acoustics and amenity, whether it be environmental or internal spaces. Other major streams will address airport / road / railway noise, standards and guidelines including those from EPAs, underwater acoustics, marine bioacoustics and vibration.

Acoustics 2013 Victor Harbor will provide in-depth coverage of many topics of interest to professionals in related fields including educationalists, consultants, planners, developers, government authorities, and EPA/noise officers

VENUE

Acoustics 2013 Victor Harbor will be held at the McCracken Country Club. The 4.5 star McCracken Country Club offers guests luxurious accommodation in the beachside township of Victor Harbor. The country club highlights are its golf course, day spa and the gorgeous panoramic view of Hindmarsh Valley. Visit www.countryclubs.com.au/mccracken/

TOPICS

In addition to the main conference themes, Acoustics 2013 Victor Harbor will include sessions on:

- Environmental acoustics
- Industrial acoustics
- Wind turbine noise
- Low frequency noise
- Internal spaces and amenity
- Architectural acoustics
- Underwater acoustics
- Marine bioacoustics
- Legislation and standards
- Transportation noise

WORKSHOPS

A series of workshops are planned. The following workshop will be held:

- Flow induced noise

For up-to-date information regarding the Acoustics 2013 Victor Harbor conference, please visit the conference website: www.acoustics.asn.au/joomla/acoustics-2013.html