Estimation of Underwater Noise
- learning lessons from air acoustics

Dick Hazelwood, R&V Hazelwood Associates LLP,
consultant to the National Physical Laboratory, UK

Learning lessons from air acoustics - and vice versa

- Noise has troubled humans for a long time, and a great deal of research has been done on ways to measure it and present the data. Noise can damage hearing but also cause annoyance.
- Most people if asked to describe the decibel will think of the dBA level used to assess its impact on a typical human subject
- The topic is very complex and it has not been easy to achieve a consensus on the substantial simplifications embodied in this decibel standard scale.
- As an example, the choice of the "A weighting" of human frequency response is still the subject of comparative testing.
- Recent work includes the effects of noise in clubs and pubs on nearby residents, where again the A weighting has been found to give the best correlation with annoyance.

•But what annoys an oyster?
or any other sea creature?

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The integration of responses- both in time and frequency

- To achieve a single value criterion, it is necessary to integrate a large number of measurements.
- Noise energy can be considered as a spectrum of many different frequencies, each of which evokes a different response in a human subject. Here the A weighting has been adopted almost universally.
- The various spectral levels will also vary with time, and it is then necessary to integrate over time.
- The dBA Leq levels are integrated as acoustic energy, then divided by the time of the recording to give an energy average.
- This has been adopted in many circumstances despite the evidence that other factors are important, as a “first cut”. Further analysis can then be done in areas seen to be critical.
- Underwater sound energy levels (SEL) have recently been adopted for some applications

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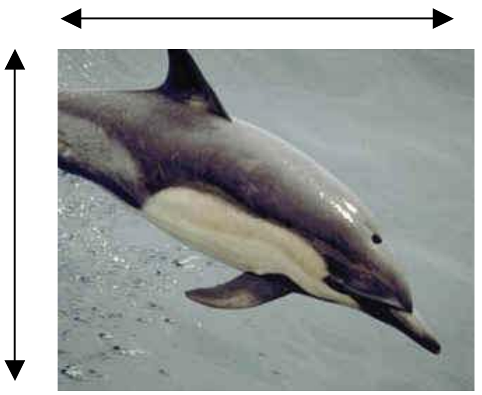
The "dose" characteristic of Sound Energy Levels

A nominal $1m^2$ through which sound energy passes



The 20 J/m^2 TTS limit is the integration of the intensity (W/m^2) over the period of the trial. Watts measure the rate of flow of energy in Joules (J). Conversely if the variation of wattage with time is measured, the total energy is obtained by integration (summation).

So if indeed a dolphin had stayed in place over the trial, and had avoided suffering any shift in hearing threshold from this dose, when can the next trial start?

Sound flowing from the distant source

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Differences from airborne sound

Parameter	Air	Water
Sound speed (m/s)	344 (20 ºC and 50 % humidity)	1521 (20 ºC, depth 10 m, salinity 35 parts per thousand)
Acoustic impedance (Pa.s/m)	~ 420	~ 1,500,000
Absorption at 1 kHz (dB/km)	~ 5 (30 % humidity)	~ 0.06 (seawater)
Reference level (µPa)	20	1
Frequency range	20 Hz to 20 kHz (mainly audible range)	<1 Hz to > 1MHz

How can we simply compare different types of noise source?

- Amongst other issues we are thus interested in –
- Tonal audiometry of many creatures – the lowest level of a pure tone that can be detected in quiet conditions
- How such detection is influenced by broad band noise - the masking bandwidths over which this occurs
- The extent to which a simple energy integral can represent this influence
- Additionally there will need to be considerations of the levels at which both permanent and temporary damage can occur
- But in this talk I will concentrate on the physics

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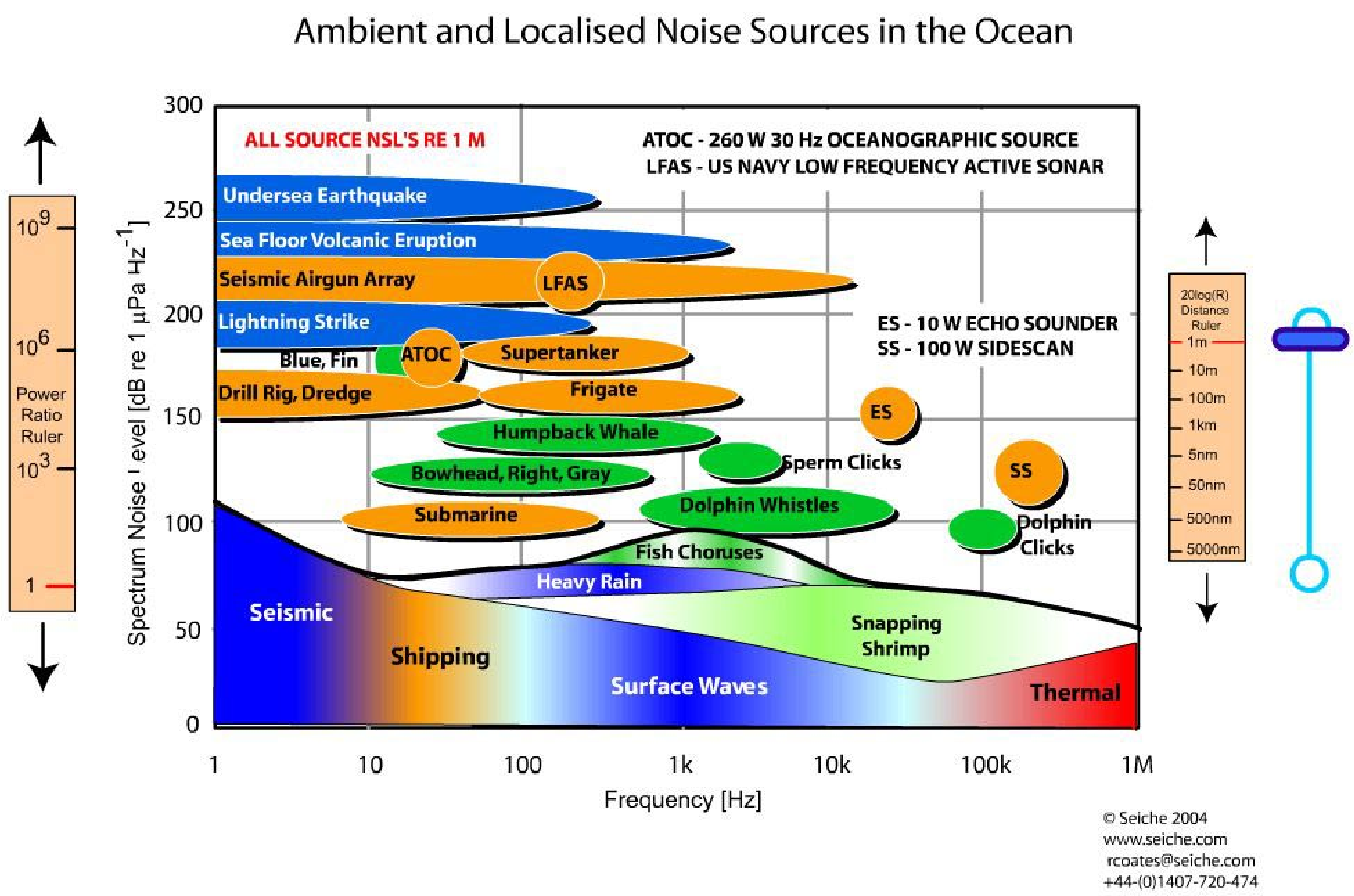

This diagram by Prof Coates provides coarse comparisons of sound sources, but to compare them with distributed noise the range matters

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"Underwater acousticians do it differently" with concepts not commonly used in airborne acoustics

- Whilst in the matter of regulation, airborne acoustics has a long history, worthy of detailed study, the work done by sonar engineers has also led to several concepts not widely used in air.
- A notable item is the concept of a source level, used to characterise the output from a source in a specific direction.
- The sound power level, used to regulate airborne noise sources such as domestic fridges, lawnmowers etc measures the total output in all directions in Watts, or in dB re 1 picoWatt
- The source output in a "free field" with no reverberation can be measured by the sound pressure at a known distance, either specified by both pressure and range, or by the pressure range product which is constant in these conditions. The source level is the decibel scale version in dB re 1 μPa·m widely used underwater.

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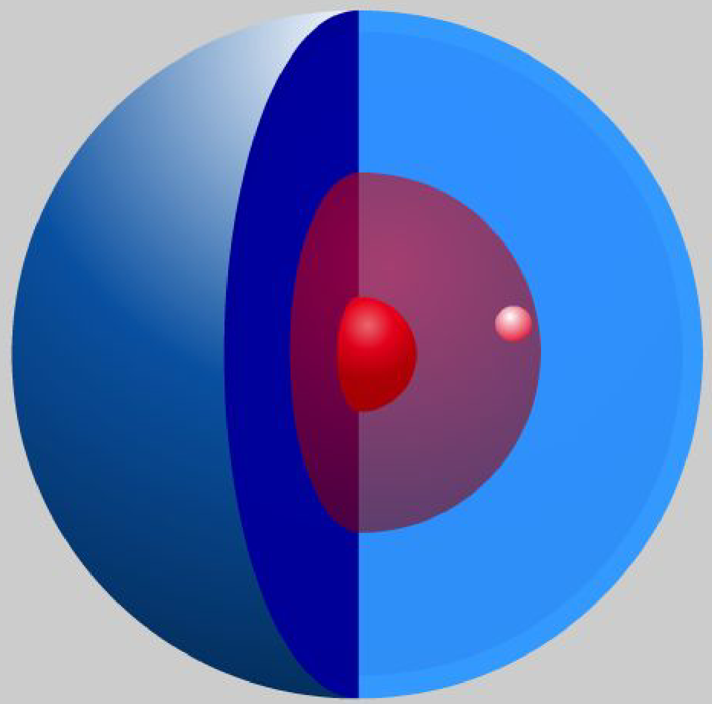
Sound emitted by a *simple* source showing a single pulsation cycle



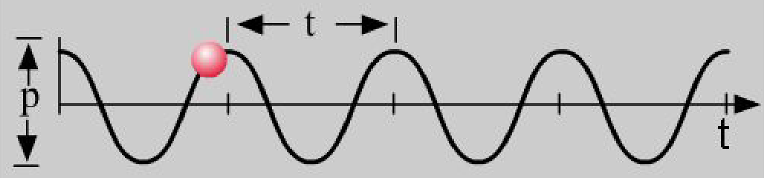
Spherically spreading sound waves

As sound energy flows away from this simple source, the fluctuating *acoustic pressure* falls as the inverse range. Thus pressure, when multiplied by the range, forms a characteristic constant source output. When converted to a decibel scale this becomes the *source level*.

(may need a click to activate)

Click to view pressure versus range

Pressure versus time



This pure tone is a sinusoidal variation at a single frequency. The period t is shown between successive compression peaks. The acoustic pressure p is here shown as the peak to peak variation.

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This shows a simple source such as a pulsating sphere, radiating sound to a hydrophone (the smaller sphere).

This is available at npl.co.uk/acoustics/techguides/concepts

Underwater noise - basics

Divide the assessment of noise into stages:

- noise emission from sources
  - requires source to be characterised
  - as detailed **source levels** or overall **sound power**
- sound transmission - the **transmission loss**
  - propagation can be highly complex
  - depends on boundary conditions and environmental conditions
- background noise – the **spectral distribution**
  - the ambient noise level in the ocean
- sound reception
  - the sensitivity of the receiver (or animal) at the location where the sound is detected – the **audiometry thresholds**

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A simpler way??

- It is all extremely complicated.
- It is also extremely expensive, and often not done.
- We need methods to provide simpler preliminary estimates
- Comparisons can then be made to draw attention to the more serious, and concentrate available efforts there
- However, to provide such preliminary assessments, commercial companies will need encouragement that this is not the “thin end of the wedge”
- Where risks are indeed shown to be modest, this needs to be accepted.

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