

Methods note · Sea ice and ocean

# What a decibel number needs beside it

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Fictional author and institute · Editorial demonstration, not peer reviewed

## ABSTRACT

A decibel value becomes comparable only when its physical quantity, reference, frequency support, averaging interval, and calibration are known. This methods note synthesises laboratory guidance and acoustic-methods research to distinguish sound pressure level, peak measures, sound exposure, and spectral density. Hypothetical calculations explain the conventional reference difference between air and water, the effect of duration on exposure, and why averaging logarithmic levels can differ from an energy-equivalent average. The discussion also separates received levels from source levels and pressure measurements from particle motion. It does not establish current regulatory thresholds or biological equivalence between equal exposures. The practical result is a reporting minimum that prevents an apparently precise acoustic comparison from concealing different quantities, processing choices, or measurement limits.

Keywords: underwater sound · decibels · sound pressure · sound exposure · acoustic calibration

A source-based editorial text, not a report of original Still North research. Examples and imagery are illustrative.

A recording is described as 120 decibels. Without a reference quantity, frequency range, averaging interval, and measurement definition, the number is not ready for comparison. This is more than a missing footnote. Two analysts can assign different levels to the same waveform by using different averaging windows, while air and underwater measurements conventionally use different reference pressures. Neither difference necessarily means that the physical sound changed.

This methods note draws on the National Physical Laboratory's underwater measurement guide, a primary analysis of transient metrics, and calibrated acoustic-habitat methods. It develops worked comparisons of pressure, exposure, and averaging. The numerical cases are hypothetical and are not measurements of Arctic vessels, mammals, or ambient sound. The note addresses measurement interpretation, not current regulatory thresholds or a universal biological dose-response relationship.

## The reference is part of the quantity

For root mean square sound pressure  $p$ , sound pressure level is  $20 \log_{10}(p/p_0)$ , where  $p_0$  is the reference pressure. The equivalent expression uses ten times the logarithm of the mean-square-pressure ratio. Underwater, the conventional reference pressure is 1 micropascal, written 1  $\mu\text{Pa}$ . A level should therefore say dB re 1  $\mu\text{Pa}$ , not merely dB. The sound pressure is the fluctuating acoustic component, not the much larger hydrostatic pressure at depth.

Take an invented root mean square pressure of 1 Pa. Since 1 Pa is one million micropascals, its underwater level is  $20 \log_{10}(1,000,000)$ , or 120 dB re 1  $\mu\text{Pa}$ . With the conventional air reference of 20  $\mu\text{Pa}$ , the same numerical pressure gives approximately 94 dB re 20  $\mu\text{Pa}$ . The 26 dB difference comes from the reference. This calculation does not say that a sound in water is equivalent to one in air for intensity, propagation, hearing, or risk.

The medium matters because pressure alone is not every acoustic quantity. Under appropriate travelling-wave conditions, converting pressure to intensity involves acoustic impedance. Near sources and reflecting boundaries, the relationship is more complicated. Many fish and invertebrates respond importantly to particle motion, which a pressure-only measurement does not directly characterise. The NPL guide explicitly separates its sound-pressure scope from those additional measurements.

## Three pressure summaries are not three spellings

Root mean square pressure summarises the squared waveform over a specified interval. Peak pressure describes the greatest magnitude during an interval, while peak-to-peak pressure spans the negative and positive extremes. For a clean sinusoid their relationships are known. For a transient with a sharp peak and a long weak tail, a fixed conversion cannot safely replace the waveform. Label the metric instead of applying a familiar sinusoidal offset to arbitrary ocean sound.

Madsen's analysis of noise transients demonstrates how averaging-window choices can change reported root mean square levels for the same waveform. This does not make root mean square pressure useless; it makes its time support indispensable. A brief high-amplitude pulse averaged over its active duration and the same pulse averaged over a minute of surrounding quiet answer different questions. A comparison that conceals the intervals is not repaired by using additional decimal places.

## A worked pressure and exposure comparison

Imagine a steady hypothetical signal with a pressure level of 120 dB re 1  $\mu\text{Pa}$  over ten seconds in a stated band. Sound exposure integrates squared pressure through time. Its

| Hypothetical steady signal | Duration   | Sound exposure level                         |
|----------------------------|------------|----------------------------------------------|
| 120 dB re 1 $\mu\text{Pa}$ | 1 second   | 120 dB re 1 $\mu\text{Pa}^2 \text{ s}$       |
| 120 dB re 1 $\mu\text{Pa}$ | 10 seconds | 130 dB re 1 $\mu\text{Pa}^2 \text{ s}$       |
| 117 dB re 1 $\mu\text{Pa}$ | 20 seconds | About 130 dB re 1 $\mu\text{Pa}^2 \text{ s}$ |

level, SEL, uses a reference of 1  $\mu\text{Pa}^2 \text{ s}$ . For a steady signal over duration  $T$ , SEL equals SPL plus  $10 \log_{10}(T/1 \text{ s})$ . Here the result is 130 dB re 1  $\mu\text{Pa}^2 \text{ s}$ . The ten-second integration changes the quantity and its reference, not just the label on the axis.

The final row illustrates an approximately equal pressure-squared exposure from a lower level over a longer time. It does not imply equal biological effects. Temporal pattern, frequency, hearing sensitivity, context, recovery, and behaviour can matter. For an actual fluctuating record, integrate calibrated squared pressure, including the defined event boundaries, rather than assuming one representative level remained constant throughout a vessel passage.

### Do not average logarithms by accident

Suppose two equal-duration intervals have hypothetical levels of 100 and 120 dB re 1  $\mu\text{Pa}$ . Their arithmetic average is 110 dB, which describes the mean of those two logged values. It is not their combined energy-equivalent level. Convert each level to a mean-square-pressure ratio, average those ratios, and convert back:  $10 \log_{10}((10^{10} + 10^{12})/2)$ , approximately 117 dB re 1  $\mu\text{Pa}$ . The louder interval dominates the pressure-squared average.

There is nothing inherently wrong with reporting medians, percentiles, or averages in logarithmic space when they answer the chosen question. The error is naming one statistic as another. A median level describes the central condition across defined samples; an energy-equivalent level weights high-amplitude intervals more strongly. A cumulative exposure describes integration over a duration. Reporting both typical conditions and episodic events can be more informative than compressing an uneven soundscape into one apparently universal loudness value.

### Frequency support and calibration change the comparison

A broadband level includes the chosen frequency band. A power spectral density describes contribution per unit bandwidth, conventionally referenced underwater to 1  $\mu\text{Pa}^2/\text{Hz}$ . Summing spectral densities requires integration over frequency, with the correct bandwidth, window normalisation, and units. A spectral-density peak and a broad-band pressure level cannot be compared numerically as though they were the same quantity. Changing frequency-bin width should not be allowed to masquerade as a change in ocean sound.

Merchant and colleagues describe the calibration chain required to convert digital recordings into absolute sound measurements. Hydrophone sensitivity, frequency response, amplifier gain, digitiser scaling, and processing all matter. A brightly coloured spectrogram may display relative digital amplitude without a calibrated pressure scale. If gain settings change between deployments, apparent increases may arise in the recording chain. Self-

noise, clipping, and flow noise also constrain which parts of a record can support a quantitative comparison.

Frequency weighting requires its own label. A weighting designed for human hearing in air is not automatically suitable for an underwater species. Even an auditory weighting appropriate to a defined marine-mammal group does not produce a direct observation of injury or population effect. Preserve the unweighted calibrated information where feasible, name the applied weighting and version, and identify the biological question for which it was selected.

### A reporting decision a reader can audit

Consider comparing a moored recorder before and after a hypothetical change in local vessel activity. Fix the frequency band and interval definition; establish comparable calibration and deployment depth; record usable effort; and inspect instrument or platform noise. Then compare distributions and source-associated events rather than selecting only the loudest day in each period. A source level inferred from propagation is not the received level measured at that recorder, and neither is automatically the level at an animal's changing position.

Limitations should say exactly what the analysis lacks. A pressure record without particle-motion measurements cannot settle every fish-hearing question. A remote fixed recorder cannot reconstruct individual exposure without a suitable spatial model. An old measurement guide cannot establish current permitting criteria. These boundaries do not erase the value of the record. They identify the additional evidence required to connect sound measurement with the proposed consequence.

The useful minimum is a complete quantity: metric, reference, band, interval, weighting, calibration basis, and location. Once these travel with the number, decibels become a compact and powerful way to compare sound. Without them, numerical precision can hide a comparison that was never physically defined.

### References

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