Cyfoeth Naturiol Cymru
Natural Resources Wales

NRW's Position on Assessing the effects of Hearing Injury from Underwater Noise on Marine Mammals

Position statement

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What is this document about?

This document sets out NRW's position on assessing significance and adverse effects on site integrity from hearing injuries (i.e. permanent threshold shift (PTS)) sustained from underwater noise generated by marine development.

Who is this document for?

The Position Statement is aimed at:

- Those within NRW who may be advising on Habitats Regulations Assessment (HRA) of Special Areas of Conservation (SACs) with marine mammal features
- NRW Marine Licensing Team, who may wish to understand how this advice should be applied
- Other Competent Authorities (CA) / regulators / UK Statutory Nature Conservation Bodies who may wish to understand our approach and consider its use in conducting HRA on sites with marine mammal features
- Developers and their consultants who wish to understand this approach and submit applications with enough information to allow the CA to assess sites with marine mammal features in the same way

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Version History

Document Version	Date Published	Summary of Changes

1.0	05-2023	Document published

Review Date: This Position will be reviewed as and when relevant new evidence becomes available.

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1. Introduction

Exposure of marine mammals to loud sounds, such as those generated by pile driving, can lead to reductions in hearing sensitivity known as “threshold shifts”. These can either be temporary (TTS), or permanent (PTS) and can be caused by both impulsive and continuous noise. In the UK, PTS is considered an injury (SNCBs 2010). Threshold shifts are assessed using the most recent set of auditory injury criteria (currently Southall et al 2019), and these thresholds are estimated on TTS data, since it is unethical to cause PTS in test animals. To account for the different aspects of sound exposure and duration dual metrics (unweighted SPL_{peak} and frequency-weighted SEL) are used to assess for PTS. Exceeding either threshold by the specified level is sufficient to result in PTS onset. Sound sources are defined as impulsive or continuous based on their characteristics at the source (Southall 2007, 2019). To avoid complexity, impulsive noise sources are distinguished based on the the nature of the sound at the source despite known effects where impulsive noise gradually becomes more continuous at greater ranges (Southall, 2019). The Southall et al (2019) guidelines have been endorsed by the UK’s Statutory Nature Conservation Bodies (SNCBs), and are a revision of and supercede the older Southall et al (2007) guidelines.

The hearing injury pathway requires assessment under the Marine Works (EIA) Regulations (2007) or the Conservation of Species and Habitats Regulations (2017). Although the process for assessing hearing injury is the same for both an Environmental Impact Assessment (EIA) and Habitats Regulation Assessment (HRA), significance can be levied at different reference population levels. This is typically at Management Unit (MU) level for an EIA, and either at the site level or the MU level for an HRA.

This document sets out NRW’s advice on how to assess significance and adverse effect on site integrity (AEOSI) from PTS from underwater noise, including which metrics to use and consider for mitigation, and assumptions to make regarding characteristics of impulsive noise. NRW has produced a parallel technical appendix which further informs this position statement.

2. NRW position on assessing significance and AEOSI from PTS

2.1 Assessing significance and AEOSI from PTS

To assess the potential impact of PTS, we recommend the use of appropriate bespoke modelling to predict the spread of sound from its source over an increasing area (referred to as sound propagation). The sound level decreases with range, and the distance from the source at which the sound decreases to below the level of PTS onset (the PTS threshold) can be determined. The number of animals affected by PTS can be estimated by multiplying the maximum area where PTS will occur by the species density.

To assess the level of effect from PTS and whether that is significant (in an EIA) or an AEOSI (in an HRA), we recommend the use of the Interim Population Consequences of Disturbance (IPCoD) model (Harwood et al 2013). Here, the number of animals with PTS is compared to the underlying reference population. For EIA purposes the reference population used is the Management Unit (MU), whereas for HRA conservation objectives relate hearing injury to population viability either at the site level or the management unit level where typically the species should be maintaining itself in the long term as a viable component of the site.

If, as a result of PTS, a population shows a continued decline of >1% per year (versus a modelled unimpacted reference population) over a set period of time (e.g. the first 6 years, based on the former Favourable Conservation Status (FCS) reporting period), then there is a high likelihood that a significant effect and AEOSI cannot be ruled out. This is dependent on the case specifics and subject to expert judgement (for further information on the 1% threshold, refer to the technical appendix and NRW's position on determining AEOSI in relation to potential anthropogenic removals (NRW, 2022)). NRW may consider alternative approaches where adequately justified (e.g. Population Viability Analysis, PVA) in consultation with NRW at the scoping stage.

2.2 Metrics and assumptions

When assessing the impacts of impulsive noise, we recommend that when conducting an assessment: (1) both metrics (SPL_{peak} and SEL) should be evaluated and the one predicting the largest range of impact used for the assessment (as recommended by Southall et al 2019), and (2) that impulsive noise will retain its characteristics as it propagates.

3. Metrics to use and assumptions on TTS/PTS onset and impulsive noise.

In line with Southall et al (2019) we advise the use of dual metrics for impulsive noise: unweighted SPL_{peak} and frequency-weighted SEL. These metrics are needed to account for the different aspects of sound exposure and duration. SPL_{peak} is a measure of absolute maximum exposure at any one time, whereas SEL is a measure of the sound energy of exposure accumulated over time. These two metrics are applied under the condition that exceeding either threshold by the specified level is sufficient to result in TTS or PTS onset. The metric predicting the largest range of impact should be used for the impact assessment, and whether mitigation of this pathway is required will be determined by the assessment.

SEL can be cumulative over multiple repeated impulsive noise exposures that occur in rapid succession (e.g. a pile driving sequence). This is referred to as cumulative SEL (SEL_{cum}), and the same thresholds as SEL are used since the exposure builds over many events instead of just one. At present, criteria for TTS onset (it is unethical to cause PTS in test animals so TTS onset data are used) are based on cumulative exposure over all impulsive noise events, without taking into account recovery of hearing between successive impulses and as a result this leads to overestimates of the range of PTS onset. Some studies have shown that exposures to noise with equal SEL_{cum} but with different lengths of time between noise pulses do not result in the same amount of TTS (e.g. Kastelein et al 2014a; von Benda Beckman et al 2022). However, the current consensus is that more data is needed before we can apply these findings into noise impact assessments (Finneran 2015; von Benda Beckman et al 2020; Southall 2021). We consider that, at present, there is insufficient evidence to depart from the use of the SEL_{cum} metric. Where and when sufficient evidence and data is found to support a different approach, it may be appropriate to incorporate these in an assessment.

At ranges over several kilometres impulsive noise gradually becomes more continuous due to refraction, absorption and scattering attenuating high frequencies more than low frequencies. Sound also reflects off the surface and bottom of the sea taking different paths, thus it takes a different amount of time to arrive at a given point, lengthening the pulse (Hastie et al 2019; Martin et al 2020). In this way noise that is impulsive at the source becomes less likely to cause injury with range however we do not yet have enough data about these changes in impulsive character to be able to apply them to impact assessments (Southall 2021) although further work is ongoing. We recommend that until further evidence is available, a precautionary assumption should be made that impulsive noise keeps its impulsive characteristics (i.e. short duration, rapid onset, high amplitude) as it propagates away from the source.

4. Glossary

Some definitions useful for this position statement are given below. Here, both the official terminologies as defined in ISO18405:2017 followed by their more conventionally used equivalents have been included, although in this document the conventional terms are used.

- Continuous (non-impulsive) noise: sounds where the acoustic energy is spread over a significant time, from seconds to hours. The amplitude of the sound can vary, however it does not fall to zero for any significant amount of time. The sound may contain broadband or tonal noise at specific frequencies. Sources can include shipping, dredging, or operational noise from turbines. The metric most suitable is sound pressure level, although sound energy level can also be used if calculated over a fixed time period rather than an individual event.

- Impulsive noise: a pulsed short-duration broadband sound that a sudden onset and is often loud. Sources can include pile-driving, airguns, and detonation of unexploded ordnance (UXO). For simplicity, here we define impulsive noise sources based on their characteristics at the source, despite known effects that take place at greater ranges (over several kilometres) where impulsive noise gradually becomes more continous. The metrics most suitable are sound exposure level and peak or peak-to-peak sound pressure level.

- Sound Pressure Level (L_p / $L_{p,rms}$ / SPL / SPL_{rms}): is considered to be a measure of the average unweighted level of sound over a given measurement period, and is typically used to characterise noise and vibration from a continuous source. Derived by taking twenty times the base ten logarithm of the ratio of the root mean square sound pressure to the specified reference value (i.e. 1 μPa) (unit: dB re 1μPa)

- Peak sound pressure level ($L_{p,pk}$ / SPL_{peak}): the unweighted peak sound pressure level is the absolute maximum noise level at any one time, and is often used to characterise impulsive noise. SPLpeak is determined by measuring the maximum variation of pressure from the positive peak to zero within the wave. Also referred to as $L_{p,0\text{-}peak}$ or $SPL_{0\text{-}peak}$ (unit: dB re 1 μPa).

- Sound exposure level ($L_{E,p}$ / SEL): the sound exposure level is a measure of the sound energy of exposure accumulated over time. It is often used to assess noise from impulsive sources. Derived by taking ten times the base ten logarithm of the square of the sound pressure integrated over a specified time period (unit: dB re 1 μPa^2s).

- Single-strike sound exposure level (SEL_{ss}): single-strike SEL, the sound exposure level from a single pile strike. Also referred to as single-pulse SEL when referring to impulsive sources other than piling (unit: dB re 1 μPa^2s).

- Cumulative sound exposure level (SEL_{cum}): The SEL summed up over multiple exposures / multiple impulsive events such as for a pile driving sequence (unit: dB re 1 μPa^2s).

- Frequency weighting / auditory weighting: a process where the frequency content of a sound is weighted according to a weighting curve to obtain the sound level experienced by an animal. They are applied to SEL values but not SPL. Such frequency weighting is related to the audiograms of animals, which are graphs that show the detection threshold (y-axis) against frequency (x-axis) for a species, or group of species with similar hearing capabilities. Essentially, a weighted sound level mimics the filtering effect of a mammalian ear, where some acoustic energy is filtered out for frequencies which an animal is less sensitive to. For harbour porpoise, for example, the most commonly used weighting is the very high frequency (VHF) group audiogram in Southall et al (2019). Similarly, for bottlenose dolphin, the high frequency (HF) group audiogram is used, and for grey seal the phocids in water (PW) group audiogram is used. Other weightings exist such as M-weightings from Southall et al (2007).

5. References

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