NRW's Position on Assessing Behavioural Disturbance of Harbour Porpoise (*Phocoena phocoena*) from underwater noise

Position statement

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What is this document about?

This document sets out NRW's position on assessing the extent of behavioural disturbance of harbour porpoise from underwater noise generated during construction of offshore renewables infrastructure.

Who is this document for?

- Those within NRW who may be advising on Environmental Impact Assessment (EIA), and 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

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1.0	05-2023	Document published

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

To report issues or problems with this guidance contact: Guidance Development

Contents

1. Introduction

A number of noise generating activites can potentially result in disturbance to harbour porpose, e.g. pile driving undertaken for the installation of offshore wind turbines, or seismic surveys for oil and gas exploration. Behavioural reactions can vary in severity, ranging from sustained vigilance and brief interruptions of foraging, to elevated energy expenditure and prolonged displacement from optimal habitat. Furthermore, responses can vary depending on context, age/sex class, and individual behavioural state. Here, we consider disturbance at a biologically meaningful level, where an animal is disturbed enough to affect its survival and fecundity.

Disturbance is a pathway that requires assessment, usually under the Conservation of Species and Habitats Regulations (2017), or the Marine Works (EIA) Regulations (2007). When a competent authority carries out a Habitats Regulations Assessment (HRA), behavioural disturbance is assessed through area thresholds, whereas for an Environmental Impact Assessment (EIA) the aim is to quantify the magnitude of the impact in terms of the number of harbour porpoise disturbed.

In 2020, the Joint Nature Conservation Committee (JNCC), Natural England (NE), and the Department of Agriculture, Environment and Rural Affairs (DAERA) published guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise Special Areas of Conservation (SACs) as part of an appropriate assessment under the Habitats Regulations (2017). The JNCC (2020c) guidance recommends the use of Effective Deterrent Ranges (EDR)s - i.e. the radius of a circular area assumed to be disturbed - for harbour porpoise for a variety of sound sources. Although the use of an EDR can be a useful, practical way of calculating the area over which effects may occur, NRW considers that there is still considerable uncertainty in the evidence underpinning the calculation of these EDRs. NRW therefore did not endorse this guidance to retain some flexibility in approaches to the management of noise where NRW is the consenting / licensing authority, although note that the guidance still applies to Welsh waters beyond 12nm.

In this document, we outline NRW's position on how behavioural disturbance of harbour porpoise from underwater noise should be assessed when conducting (1) an HRA, and (2) an EIA.

2. NRW Position on assessing behavioural disturbance of harbour porpoise (*Phocoena phocoena*) from underwater noise

2.1 HRA

Disturbance for harbour porpoise in special areas of conservation (SACs) is defined through the spatial and temporal area thresholds set out in the SAC Conservation Objectives. Noise disturbance within an SAC from a plan/project, individually or in combination is considered to be significant if it excludes harbour porpoises from more than:

1. 20% of the relevant area of the site in any given day, or

2. An average of 10% of the relevant area of the site over a season

The thresholds are 20% daily and 10% seasonally. In this regard, an area-based assessment should be carried out to determine the spatial extent of the habitat that may experience significant disturbance.

For the purpose of carrying out an HRA, we have ranked potential methods used for quantifying the spatial extent of disturbance (i.e. 20% / 10%) in order of preference (see table 2). We advise the use of: (1) fixed noise thresholds after appropriate bespoke noise modelling is carried out, over (2) EDRs where these exist.

Alternative approaches to the best recommended methods in table 2 will be considered on a case-by-case basis in consultation with NRW at the scoping stage, their use would need to be justified using evidence to support that approach.

2.2 EIA

For the purpose of carrying out an EIA, we have ranked potential methods to determine the number of animals disturbed in order of preference. We advise the use of: (1) dose-response (D/R) curves where available (currently only for pile driving), over (2) fixed noise thresholds, over (3) EDRs to obtain the predicted number of animals potentially disturbed. For (1) and (2) these should be applied after appropriate bespoke noise modelling is carried out.

For all noise sources except for pile driving, we advise referring to the recommended assessment options in table 2. Alternative approaches to the best recommended methods will be considered on a case-by-case basis in consultation with NRW at the scoping stage, their use would need to be justified using evidence to support that approach.

3. Assessment methods

There are three key methods that have been used in HRAs and EIAs to assess the potential for disturbance of marine mammals: effective deterrent ranges (EDR), fixed noise thresholds and dose-response (D/R) curves.

EDRs as applied in (JNCC 2020c), are area-based thresholds defined by Tougaard et al. (2013) as reflecting the overall loss of habitat that would occur if all animals vacated an area within the EDR, being equivalent to the mean loss of habitat per animal. Different EDRs have been designed to represent noise sources for example: seismic (airgun arrays) surveys, monopiles, and unexploded ordnance (UXO). While these are based on field studies (e.g. Dähne et al. 2013; Tougaard et al 2013; Brandt et al 2018), they assume that the impact range is the same irrespective of variations in source level and site-specific environmental conditions.

Fixed noise thresholds are based around a noise level above which it is assumed that all animals are disturbed. They typically rely on modelling to determine at what distance from a noise source this occurs. Fixed noise thresholds can be generic (e.g. based on sound level but not specific to any sound source or species), sound-source specific (e.g.

specifically for airguns) or species and sound-source specific (e.g. for harbour porpoise from pile driving). A key benefit is that when used, site-specific underwater noise modelling can take into account the propagational effects from source-specific sound characteristics (e.g. level, frequency spectrum and/or impulsiveness of the sound), as well as site-specific environmental variables (e.g. sediment, depth).

D/R curves build on the fixed noise threshold approach by assuming that not all animals in an impact zone will respond to disturbance, and that the response will gradually decrease with increasing distance from the noise source. Therefore, the probability of a response, and the proportion of animals experiencing behavioural disturbance, will depend on the "dose" (i.e. the amount of noise) received. The dose can either be given as the distance from the sound source, or the weighted or unweighted sound level experienced by the animal. This method allows for more realistic assumptions about animal response, which is supported by a growing number of studies. There is good evidence that behavioural responses diminish with decreasing received level and therefore D/R curves are more representative of actual animal response compared to EDRs and fixed noise thresholds.

4. Approach taken to inform the HRA

Disturbance of harbour porpoise in special areas of conservation (SACs) is defined through the spatial and temporal area thresholds set out in the Conservation Objectives. Noise disturbance within an SAC from a plan/project, individually or in combination is considered to be significant if it excludes harbour porpoises from more than:

1. 20% of the relevant area of the site in any given day, or
2. An average of 10% of the relevant area of the site over a season

In this regard, an area-based assessment should be carried out to obtain the area of habitat ensonified to a level that might produce significant disturbance.

For the purpose of carrying out an HRA, we have ranked potential methods used for quantifying the spatial extent of disturbance (i.e. 20% / 10%) in order of preference (see table 2). We advise the use of: (1) fixed noise thresholds after appropriate bespoke noise modelling is carried out, over (2) EDRs where these exist.

We recommend that bespoke noise modelling is required for any proposed activity that may generate high levels of impulsive noise (e.g. pile driving, seismic surveys). An unweighted noise threshold of 143 dB re 1µPa (or 103 dB re 1µPa VHF-weighted) single strike sound exposure level (SEL_{ss}) (Brandt et al 2018; Heinis et al 2019) is recommended to represent the minimum fixed noise threshold at which significant disturbance would occur from impulsive noise sources. This fixed noise threshold is the modelled average of six different studies of full-scale pile driving operations (see table 1) and thereby represents a large amount of empirical data (Tougaard et al 2021). The 143 dB re 1µPa noise contour should be displayed on a map of the area to determine the extent of the SAC that would be ensonified to this level of noise disturbance.

Table 1. Summary of VHF-weighted thresholds for behavioural responses to pile driving noise derived from six different studies (adapted from Tougaard, 2021). Note that the difference between a VHF-weighted and an unweighted sound exposure level is approximately 40 dB.

Study	Threshold (VHF-weighted)	Comments
Dähne et al. (2013)	100 -115 dB re 1μPa	Based on reaction distance between 10-25 km at Alpha Ventus Offshore Wind Farm (OWF)
Kastelein et al. (2013)	95 -101 dB re 1μPa	Playback of pile driving noise in captivity
Tougaard et al. (2015)	95 dB re 1μPa	Generalised threshold based on data from pile driving and acoustic deterrent devices (ADDs)
Brandt et al. (2018)	103 dB re 1μPa	Modelled threshold based on six OWFs in the German Bight
Graham et al. (2019)	110 dB re 1μPa	Audiogram-weighted threshold from pile driving at Beatrice OWF
Kastelein et al. (2021)	< 100 dB re 1μPa	Playback of low-pass filtered pile driving noise in captivity

EDRs are an approach that should be applied when there is a need to assess disturbance in relation to a temporary habitat loss. They should not be used as a screening distance in HRA as they only represent a distance for quantifying an impact (significant disturbance of harbour porpoise) usually in the Appropriate Assessment stage, and not a screening distance for HRA (the Likely Significant Effect, LSE, stage). For the LSE stage the relevant MMMU should be used given the highly mobile nature of the species feature of SACs and functional linkage to areas outside of the SAC boundaries (NRW, 2022)

We do not recommend the use of D/R curves for area-based assessment; although there is a strong link between the area of habitat and number of animals it supports, loss of habitat quality is a binary event as an area is either ensonified by a sound at a given level (and hence "lost"), or not. This differs from behavioural disturbance of animals which occurs over a continuum and relates to the numbers of animals affected; the spatial / temporal thresholds for HRA are not concerned with numbers of animals. This is because harbour porpoise is a highly mobile species, able to travel 100s of km in a short period of time, part of large wide-ranging population with highly variable numbers of animals spatially and temporally hence the concept of a “site population” does not apply. The chosen approach for assessing the impacts of noise on harbour porpoise SACs was grounded in quantifying the loss of habitat available to harbour porpoise as a result of disturbance, given that the SACs were designated based on higher persistent densities than other areas within the harbour porpoise management unit (MU) (JNCC 2020a, b)

Table 2. Table of best recommended and alternative assessment options to inform the HRA for piling, seismic, sonar, UXO, and continuous noise for harbour porpoise. NRW advise the use of the best recommended option column, but may consider other approaches highlighted in column 3 where adequately justified. W_{vhf} = weighting function for very high frequency cetaceans (Southall et

al 2019); M-W_{vhf} = M-weighting function for very high frequency cetaceans (Southall et al 2007); Type II-W = type II weighting function (Finneran & Jenkins 2012).

Source	Best recommended option	Less preferred options
Pile driving	143 dB SEL_{ss} (Tougaard, 2021); 145 dB SEL_{ss} (Lucke et al 2009); or 140 dB SEL_{ss} (ASCOBANS 2014)	160 dB SPL_{rms} level B disturbance (NMFS 1995, 2005); 140 dB SPL_{rms} low level disturbance (NMFS 2005); EDR of 26 km for a monopile (JNCC 2020); EDR of 15 km for a monopile with noise abatement or a pin pile (JNCC 2020)
Seismic surveys	143 dB SEL_{ss} (Tougaard, 2021); 145 dB SEL_{ss} (Lucke et al 2009); or 140 dB SEL_{ss} (ASCOBANS 2014)	160 dB SPL_{rms} level B harassment (NMFS 1995, 2005); 140 dB SPL_{rms} low level disturbance (NMFS 2005); EDR of 12 km for a seismic airgun survey (JNCC 2020);
Geophysical surveys (Sub-bottom profilers and Sonar)	160 dB SPL_{rms} level B harassment (NFMS, 2005)	120 dB SPL_{rms} for sonar with high duty cycles (Finneran & Jenkins, 2012) EDR of 5 km (JNCC 2020)
Unexploded ordnance	140 db SEL (W_{vhf}) or 196 dB SPL_{peak} TTS onset threshold (Southall et al 2019)	183 dB SEL (M-W_{vhf}) or 224 dB SPL_{peak} TTS onset threshold for single detonations only (Southall et al 2007); 141 dB SEL (Type II-W) for multiple detonations only (Finneran & Jenkins 2012); 160 dB SPL_{rms} level B harassment for multiple detonations only (NMFS 1995; 2005); 140 dB SPL_{rms} low level disturbance for multiple detonations only (NMFS 2005); 26 km EDR for high order detonation (JNCC 2020); 5 km EDR for low order detonation (JNCC 2020).
Continuous noise	120 dB SPL_{rms} (NFMS 1995, 2005)	174 dB $SPL_{peak\text{-}peak}$ (Lucke et al 2009); 140 dB SPL_{rms} profound and sustained avoidance (Southall et al 2007); 90-120 dB SPL_{rms} low level disturbance (Southall et al 2007)

Unlike most impulsive noise sources, detonations of UXO are generally single events, and a detonation will only cause temporary startle responses (Finneran & Jenkins 2012; JNCC 2020c). For assessing disturbance from the detonation of UXO, we recommend an interim approach of using the latest temporary threshold shift (TTS) fixed thresholds (currently Southall et al 2019), where TTS is a temporary reduction in hearing sensitivity caused by exposure to loud sound. This approach is proposed because existing empirical models for UXO are known to overestimate source levels due to the dual assumptions of a mid water charge and no deterioration of the explosive with time. Limited attempts have been made to model explosive sources on the seabed (Robinson et al 2022). Until more accurate models are developed, the use of a TTS threshold is accepted, despite the fact that being a TTS threshold, it is inherently less conservative given that it marks the boundary between the highest level of disturbance and the start of physical impacts on the auditory system.

For geophysical surveys, sub-bottom profilers, and active sonar, we recommend the use of a 160 dB re re 1μPa SPL_{rms} fixed threshold (NMFS 1995; 2005), although for some types of active sonar with higher duty cycles, a threshold for continuous noise of 120 dB re 1μPa SPL_{rms} can be more appropriate (Finneran and Jenkins, 2012).

Finally, for continuous noise sources including drilling, dredging, vibratory pile driving, vessel noise, and operational noise we recommend the use of the level B harassment level 120 dB re 1μPa SPL_{rms} threshold (NMFS 1995; 2005). Level B harassment refers to acts that have the potential to disturb (to a biologically significant degree - but not injure) a marine mammal or marine mammal stock in the wild by disrupting behavioural patterns, including: migration, nursing, breeding, feeding, or sheltering. Threshold levels at which both captive (e.g. Kastelein et al., 2005; Kastelein et al., 2000) and wild harbour porpoises (e.g. Johnston, 2002) responded to sound (e.g. acoustic harassment devices, acoustic deterrent devices, or other non-impulsive sound sources) is very low (an SPL of approximately 120 dB re 1 μPa) (Southall et al 2007; Finneran & Jenkins, 2012). Although the NMFS thresholds were developed based on mysticete behavioural data, they appear to match the levels at which harbour porpoise react to continuous noise and thus can be applied to them.

5. Approach taken for EIA

In the UK, the EIA process typically involves a quantitative assessment of the effects of the worst-case impact pathway(s) from a maximum design scenario. Here, we describe the prediction of the number of harbour porpoise disturbed, the magnitude of the effect, and how it relates to the population / MU.

For the purpose of carrying out an EIA, we have ranked potential methods to determine the number of animals disturbed in order of preference. We advise the use of: (1) dose-response (D/R) curves where available, over (2) fixed noise thresholds, over (3) EDRs to obtain the predicted number of animals potentially disturbed. For (1) and (2) these should be applied after appropriate bespoke noise modelling is carried out.

For all noise sources except for pile driving, we advise referring to the recommended assessment options in table 2. For impact pile driving, harbour porpoise dose-response curves have been created (Graham et al 2019, 2017; Neart na Gaoithe, 2018; Thompson et al. 2013) and we recommend their use. We endorse the use of D/R curves since this allows for more realistic assumptions about how the numbers of harbour porpoise that respond vary with dose, as there is good evidence that behavioural responses diminish with decreasing received sound level. EDRs can also be used to determine the number of animals disturbed in some instances where no other information is available, although these are an area-based threshold intended to represent the mean loss of habitat per animal.

The total number of animals disturbed can then be estimated by multiplying either the probability of a behavioural response (for a D/R curve) or the extent of ensonification (for a fixed noise threshold or an EDR) by harbour porpoise density. These numbers can then be related to the total size of the population at the MU level, and a judgement made as to whether this is significant or not.

6. 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. SPL_{peak} 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).

- Peak to peak sound pressure level ($SPL_{peak\text{-}peak}$): the unweighted peak to peak sound pressure level is equivalent to the sum of the magnitides of the peak positive and peak negative pressures, although it is not specifically defined by the ISO (2017) standard. $SPL_{peak\text{-}peak}$ is generally twice the magnitude of the peak level (i.e. 6 dB re 1 μPa higher).

- 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 $\mu Pa^2 s$).

- Single-strike sound explosure 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 $\mu Pa^2 s$).

- 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 $\mu Pa^2 s$).

- 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, the most commonly used weighting is the very high frequency (VHF) group audiogram in Southall et al (2019), although other weightings exist such as M-weightings from Southall et al (2007).

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