Review and recommendations on assessment of noise disturbance for marine mammals

NRW Evidence Report No. 529

Sinclair, R.R.[(1)]; Kazer, S.[(2)]; Ryder, M.[(1)]; New, P.[(2)]; Verfuss, U.K.[(1)]

(1) SMRU Consulting; (2) GoBe Consultants Ltd

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Mae’r broses o asesu effeithiau amgylcheddol yn ei gwneud yn ofynnol casglu data er mwyn nodi ac asesu'r effeithiau posibl a achosir gan ddatblygiad, ac er mwyn nodi unrhyw effeithiau sylweddol, gan gynnwys effaith aflonyddu. Fodd bynnag, ar hyn o bryd, nid oes unrhyw ddogfennau sefydledig ag arweiniad rheoliadol, a bach iawn o erthyglau gwyddonol cyhoeddedig a geir, sy'n darparu cyngor eglur ar y dull o asesu'r graddau y mae sŵn o dan y dŵr yn aflonyddu ar rywogaethau o famaliaid morol. Mae'r dull arferol o gynnal asesiad o'r effaith amgylcheddol yn cynnwys pennu trothwy y rhagwelir y bydd yr effaith aflonyddu'n digwydd hyd ato, a hynny er mwyn cyfrifo nifer yr anifeiliaid o fewn yr ystod hon y mae'n debygol y ceir effaith arnynt. Ceir sawl trothwy aflonyddu gwahanol a ddefnyddiwyd ar gyfer cynnal asesiadau o'r effaith amgylcheddol ar gyfer mamaliaid morol, gan gynnwys cwmpasau atal effeithiol (EDR), trothwyon sŵn sefydlog, a throthwyon dos–ymateb. Diben yr adroddiad hwn yw rhoi crynodeb o'r trothwyon aflonyddu gwahanol a ddefnyddiwyd wrth gynnal asesiadau o'r effaith amgylcheddol ac Asesiadau Rheoliadau Cynefinoedd yn flaenorol (yn y DU a thramor) ar gyfer amrywiaeth o ffynonellau sŵn gwahanol. Mae'r adroddiad yn crynhoi buddion a chyfyngiadau'r trothwyon aflonyddu gwahanol sydd wedi cael eu defnyddio, ac yn cynnig amlinelliad o'r dulliau gwahanol ar gyfer cynnal asesiadau o'r effaith amgylcheddol ac Asesiadau Rheoliadau Cynefinoedd, o safbwynt aflonyddu, a weithredwyd yn y DU, yn ogystal ag amlinellu cymhariaeth ohonynt â'r dulliau a ddilynwyd mewn gwledydd eraill fel yr Almaen, Denmarc, yr Iseldiroedd, UDA, a Seland Newydd.

Gan gofio nad oes unrhyw arweiniad ar gael, ac o ganlyniad i'r ffaith fod gwybodaeth newydd wedi dod i law dros amser, mae'r asesiadau o'r effaith amgylcheddol a gynhaliwyd yn y DU wedi defnyddio amrediad eang o ddulliau o asesu'r graddau y mae ffynonellau sŵn o dan y dŵr yn aflonyddu ar famaliaid morol. Yn y bôn, ceir y gwahaniaethau canlynol rhyngddynt:

- y trothwy a ddefnyddir i asesu graddau'r aflonyddu (ceir amrywiaeth sy’n cynnwys cwmpasau atal effeithiol, trothwyon sŵn sefydlog, a chromliniau dos-ymateb)
- y math o amcangyfrif dwysedd a ddefnyddir ar gyfer cynnal asesiad o'r effaith feintiol (sy'n amrywio o amcangyfrifon dwysedd unffurf rhanbarthol ar raddfa fawr i arwynebau dwysedd ag eglurder gofodol)
- y diffiniadau o faint yr effaith a sensitifrwydd y derbynyddion a ddefnyddir i benderfynu ar ba mor sylweddol yw effaith (sy'n amrywio rhwng diffiniadau meintiol ac ansoddol)
- p'un a ddefnyddir modelu poblogaethau ynteu beidio i benderfynu p’un a yw'r lefelau aflonyddu a ragwelir yn debygol o achosi newid ym maint neu drywydd hirdymor y boblogaeth

Mae'r adolygiad hwn yn amlygu y ceir buddion a chyfyngiadau ar gyfer pob trothwy aflonyddu o'u cymhwyso i asesiad o'r effaith amgylcheddol. Er enghraifft, wrth ddefnyddio cwmpasau atal effeithiol, tybir bod pellter sefydlog gyfystyr â'r cynefin a gollir gan anifeiliaid unigol ar gyfartaledd, a hynny heb ystyried y gwahaniaethau a geir rhwng newidynnau amgylcheddol a newidynnau sy'n benodol i'r ffynhonnell. Wrth ddefnyddio trothwyon sŵn sefydlog, tybir yr aflonyddir ar bob anifail sy'n derbyn sŵn sydd uwchlaw lefel benodol, ac mae'r dull hwn yn ei gwneud yn ofynnol cyflawni gwaith modelu ar y sŵn o dan y dŵr, sy'n benodol i'r ffynhonnell a'r safle, er mwyn cyfrifo'r ardal sydd o fewn y trothwy. Gellir hefyd cyfrifo nifer yr unigolion yr aflonyddwyd arnynt o'r ardal a amlygwyd i sŵn o drothwy sŵn (neu gwmpas atal effeithiol). Mae cromliniau dos–ymateb yn adeiladu ar y dull trothwy sŵn sefydlog trwy ychwanegu'r rhagdybiaeth na fydd pob anifail o fewn y parth effaith yn ymateb, ac y bydd yr ymateb hwnnw'n lleihau'n raddol wrth i'r pellter o ffynhonnell y sŵn gynyddu. Felly bydd tebygolrwydd ymateb, ac, o ganlyniad i hynny, cyfran yr anifeiliaid sy'n profi aflonyddu ymddygiadol, yn dibynnu ar y “dos” y mae'r unigolion hynny'n ei ganfod. O'i gymharu â'r dull cwmpas atal effeithiol a'r dull trothwy sŵn sefydlog, a phan gaiff ei gymhwyso yng nghyd-destun nifer yr anifeiliaid yr aflonyddir arnynt, mae cymhwyso cromlin dos–ymateb yn ei gwneud yn bosibl ffurfio rhagdybiaethau mwy realistig ynghylch y ffordd y mae ymateb anifeiliaid yn amrywio gyda'r dos. Ochr yn ochr â chrynodeb o'r trothwyon aflonyddu a gymhwysir wrth gynnal asesiadau o'r effaith amgylcheddol, mae'r adroddiad yn cyflwyno enghraifft weithiol sy'n cymharu'r canlyniadau a geir o ganlyniad i ddefnyddio trothwyon aflonyddu gwahanol ar safle damcaniaethol gan ddefnyddio dwyseddau posibl gwahanol.

Er bod angen ystyried pob rhywogaeth o famaliaid morol yn ystod proses o asesu effeithiau amgylcheddol yng Nghymru, ac er bod y broses o asesu effeithiau amgylcheddol yn llywio’r Asesiad Rheoliadau Cynefinoedd yn y pen draw, mae'r broses o gynnal Asesiad Rheoliadau Cynefinoedd yn canolbwyntio ar ystyried y dolffin trwynbwl, y llamhidydd a'r morlo llwyd, ac mae chwe Ardal Cadwraeth Arbennig (ACA) wedi'u dynodi ar gyfer y rhywogaethau hyn yn nyfroedd Cymru (ymhlith cynefinoedd a/neu rywogaethau eraill). Mae'r safleoedd hyn yn cynnwys ACA Bae Ceredigion (morloi llwyd a dolffiniaid trwynbwl), ACA Pen Llŷn a’r Sarnau (dolffiniaid trwynbwl a morloi llwyd), ACA Sir Benfro Forol (morloi llwyd), ACA Dynesfeydd Môr Hafren (llamidyddion), ACA Gogledd Môn Forol (llamidyddion), ac ACA Gorllewin Cymru Forol (llamidyddion).

Mae Asesiadau Rheoliadau Cynefinoedd yn canolbwyntio ar lefel y safle (ACA) yng nghyd-destun cynefinoedd cynhaliol ehangach a rhywogaethau dynodedig symudol iawn, a chynhelir asesiadau o'r fath mewn perthynas â'r amcanion cadwraeth perthnasol sy'n benodol i'r safle a statws cadwraeth ehangach y rhywogaethau y dynodwyd yr ACAau ar eu cyfer. Gall y broses a ddilynir wrth gynnal Asesiadau Rheoliadau Cynefinoedd fod yn wahanol felly i'r dull a ddilynir ar gyfer asesiadau o'r effaith amgylcheddol, er bod yr effaith a'r rhywogaethau dan sylw yr un peth. Mewn rhai achosion, o safbwynt aflonyddu, gwahaniaeth allweddol rhwng dull asesu’r effeithiau amgylcheddol a'r dull Asesiad Rheoliadau Cynefinoedd yw p'un a yw'r asesiad yn ymwneud â nifer yr anifeiliaid yr aflonyddir arnynt o bosib, ynteu gynnal ardal ddigonol o gynefin sydd heb ei haflonyddu o fewn yr ACA (gan gynnwys mynediad at y cynefin hwnnw). Nod y ddogfen hon yw amlinellu pa arweiniad sydd ar gael mewn perthynas â'r broses Asesiad Rheoliadau Cynefinoedd ac o ran asesu'r graddau y mae sŵn yn aflonyddu ar famaliaid morol, ond ei nod hefyd yw amlygu'r dulliau gwahanol a ddilynir wrth gynnal asesiadau o'r fath ynghyd â'r graddau y maent yn cyflawni amcanion cadwraeth sy'n benodol i'r safle ac yn benodol i'r rhywogaethau dan sylw. Eir ymlaen wedyn i ystyried perthnasedd posibl dulliau o'r fath i ACAau yng Nghymru.

Mae'r adroddiad yn gorffen gyda chyfres o argymhellion ar gyfer asesiadau o'r effaith amgylcheddol ac Asesiadau Rheoliadau Cynefinoedd. Yn sgil y diffyg arweiniad sydd ar gael, argymhellir datblygu tair dogfen ganllaw allweddol ar gyfer dyfroedd Cymru, fel a ganlyn: dogfen ganllaw reoliadol, dogfen ganllaw ar drothwyon, a dogfen ganllaw ar boblogaethau. Byddai hyn yn sicrhau y caiff yr offerynnau mwyaf cyfredol a chadarn eu mabwysiadu wrth gynnal asesiadau yn y dyfodol. Mae un o'r argymhellion allweddol ar gyfer pob trothwy aflonyddu (cwmpasau atal effeithiol, trothwyon sŵn sefydlog, neu gromliniau dos–ymateb) yn nodi y dylent ddeillio, yn ddelfrydol, o amrediad o safleoedd a ffynonellau cynrychiadol er mwyn eu dwyn ymlaen fel trothwy cyffredinol i'w gymhwyso i safleoedd eraill sy'n destun asesiad o'r effaith. Wrth i'r dechnoleg a ddefnyddir newid dros amser, ac wrth i ragor o wybodaeth am effaith bosibl sŵn o dan y dŵr ddod i law, mae'n hanfodol bwysig eu bod yn cael eu monitro er mwyn diweddaru'r trothwyon i sicrhau eu bod yn gynrychiadol ar gyfer asesiadau o'r effaith cyfredol ac yn y dyfodol. Argymhellir yn gryf hefyd felly y cynhelir y dogfennau canllaw fel dogfennau byw, er mwyn sicrhau y caiff y trothwyon a argymhellir eu diweddaru wrth i ddata newydd ddod i law.

Executive summary

The Environmental Impact Assessment (EIA) process requires the collation of data to identify and assess the potential effects of a development and to identify any significant impacts, including the impact of disturbance. However, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on how to approach the assessment of disturbance from underwater noise on marine mammal species. The typical approach of an EIA is to assign a threshold up to which the disturbance impact is predicted to occur, in order to calculate the number of animals within this range that are likely to be impacted. There are several different thresholds for disturbance that have been used for marine mammal EIAs, including effective deterrent ranges (EDRs), fixed noise thresholds and dose-response thresholds. The purpose of this report is to summarise the different disturbance thresholds that have been used in previous EIAs and Habitats Regulations Assessment (HRAs) (both in the UK and abroad) for a variety of different sound sources. The report summarises the benefits and limitations of the different disturbance thresholds that have been used and provides an outline of the different EIA and HRA approaches to disturbance that have been implemented in the UK as well as outlining how these compare to the approach taken in other countries such as Germany, Denmark, the Netherlands, USA and New Zealand.

Given that there is no guidance available, and as new information became available over time, EIAs in the UK have used a wide range of approaches to the assessment of disturbance to marine mammals from underwater noise sources. Fundamentally, these differ by:

- the threshold used to assess disturbance (varying between EDRs, fixed noise thresholds and dose-response curves),
- the type of density estimate used for quantitative impact assessment (varying between regional large scale uniform density estimates to spatially explicit density surfaces),
- the definitions of impact magnitude and receptor sensitivity used to determine the significance of an impact (varying between quantitative and qualitative definitions), and
- whether or not population modelling is used to determine if the predicted disturbance levels are likely to cause a change in the long-term population size or trajectory.

This review highlights that there are benefits and limitations to each disturbance threshold when applied to EIA. For example, EDRs assume a fixed distance which equates to the average habitat lost by individual animals, without taking into consideration differences in both environmental and source specific variables. Fixed noise thresholds assume that all animals that receive sound above a certain level are disturbed and requires source and site-specific underwater noise modelling to obtain the area within the threshold. The number of individuals disturbed can also be calculated from the area ensonified from a noise threshold (or an EDR). Dose-response curves build on the fixed noise threshold approach by adding the assumption that not all animals in an impact zone will respond, and that response will gradually decrease with increasing distance from the noise source. Therefore, the probability of a response, and thus the proportion of animals experiencing behavioural disturbance, will depend on the “dose” it perceives. Compared to the EDR and fixed noise threshold approaches and when applied in the context of the number of

individuals disturbed, the application of a dose-response curve allows for more realistic assumptions about animal response varying with dose. Alongside a summary of the different disturbance thresholds applied in EIAs, the report provides a worked example, comparing the results obtained using different disturbance thresholds at a hypothetical site using differing potential densities.

While all marine mammal species need to be considered for an EIA process in Wales and ultimately the EIA process informs the HRA, the requirement through the HRA process is focused on bottlenose dolphin, harbour porpoise and grey seal, with six Special Areas of Conservation (SACs) designated for these species in Welsh waters (among other habitats and/or species). These sites are Cardigan Bay / Bae Ceredigion SAC (grey seal and bottlenose dolphin), Pen Llŷn a`r Sarnau / Lleyn Peninsula and the Sarns SAC (bottlenose dolphin and grey seal), Pembrokeshire Marine / Sir Benfro Forol SAC (grey seal), Bristol Channel Approaches / Dynesfeydd Môr Hafren SAC (harbour porpoise), North Anglesey Marine / Gogledd Môn Forol SAC (harbour porpoise), West Wales Marine / Gorllewin Cymru Forol SAC (harbour porpoise).

HRAs are focused at site (SAC) level, in the context of wider supporting habitats and highly mobile designated species, with such assessment made in relation to the relevant site based Conservation Objectives and wider conservation status of the species for which the SACs are designated for. The assessment process followed in HRAs can therefore differ to that applied in EIAs, even though the effect and the species are the same. In some cases, a key difference in approach between EIA and HRA as regards disturbance is whether the assessment is concerned with the number of animals that may be disturbed, or with maintaining sufficient undisturbed habitat within the SAC (including access to that habitat). This document aims to outline what guidance is available with respect to the HRA process and assessing noise disturbance on marine mammals, but also the different approaches taken in such assessments and how those deliver on the site- and species-specific conservation objectives. The potential relevance of such methods for Welsh SACs is then considered.

The report concludes with a set of recommendations for both EIAs and HRAs. Given the lack of guidance available, it is recommended that three key guidance documents are developed for Welsh waters: a regulatory guidance document, a threshold guidance document and a population guidance document. This would ensure that the most up-to-date and robust assessment tools are adopted in future assessments. One key recommendation for all disturbance thresholds (EDRs, fixed noise thresholds or dose-response curves) is that they should ideally be derived from a range of representative sites and sources in order to be taken forward as a generalised threshold to other sites for impact assessment. As the technology used changes over time and more information on the potential impact of underwater noise on marine mammals becomes available, it is imperative that they are monitored in order to update the thresholds to ensure that they are representative for current and future impact assessments. Therefore it is also highly recommended that the guidance documents are maintained as live documents, to ensure that recommended thresholds and approaches are updated as new data becomes available.

Introduction

Unlike thresholds of auditory injury (Southall et al. 2007, NMFS 2016, 2018, Southall et al. 2019), there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the approach to assessment of disturbance from underwater noise on marine mammal species. Southall et al. revised the auditory injury thresholds in their 2019 publication, and updated the behavioural response review that was included in the Southall et al. (2007) publication in Southall et al. (2021). In Environmental Impact Assessments (EIAs), the impact of anthropogenic noise on the behaviour of marine mammals has been generally synonymous with displacement.

The approach to disturbance impact assessment in EIA and in general for EPS licensing is typically to assign a threshold (level of noise or defined range/area of effect for a specific noise source) at which the impact is predicted to occur, and calculate the number of animals likely to be within that range in order to predict the number of animals potentially impacted. There are several different thresholds for disturbance that have been used for marine mammal impact assessments in EIA, including effective deterrent ranges (EDRs), fixed noise thresholds and dose-response thresholds where the probability of response changes with received level or distance from source.

For HRA, the assessment process applied often, but not always, differs to that for EIA. Key to the difference is that HRA is focused at site level, takes account of site based conservation objectives and considers whether the effect would be significant or adverse on the ‘integrity’ of that site (in the context of how that site contributes to the favourable conservation status (FCS) of the species and taking account of supporting processes/wide ranging species that may occur outside the site boundary). It is apparent that many such conservation objectives, when it relates to an assessment regarding disturbance, relate more to the availability of, or access to, habitat and not necessarily to disturbance of individual animals (the latter typically the focus of EIA). That difference is most clearly evident in assessments that apply the EDR based approach (although other approaches are also applied in HRA).

The purpose of this report is to summarise the different thresholds that have been used in previous EIAs and HRAs both in the UK and abroad to assess disturbance in marine mammals from a variety of different sound sources, including pile driving, shipping, drilling, dredging, seismic activities, wave and tidal developments, and unexploded ordnance (UXO) detonation or clearance. These sound sources were selected as they are the most commonly assessed underwater noise impact pathways in UK waters. The benefits and limitations of different approaches on how to assess the impact of sound emitted by these sound sources on marine mammals are outlined, for both EIA and HRA, and recommendations are made for future assessments in Welsh waters.

This report has been structured so that key and summary information is provided in the main text. This is supported by a series of Technical Appendices should the reader wish to obtain further detail and examples.

Legislation

A number of articles of legislation afford protection to marine mammals. Information is provided for here on the legislation that underpins the HRA process. Detail on wider marine mammal legislation is available on the NRW website.

Regulation 39(1)(b) of both the Habitats Regulations (amended Conservation (Natural Habitats &c.) Regulations 1994) and the Offshore Marine Conservation Regulations (Natural Habitats, &c. Regulations 2007) (as updated by The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019) (collectively referred to as the Habitats Regulations) states that an offence has occurred if the developer:

> (b) deliberately disturbs wild animals of any such species [i.e. a European Protected Species] in such a way as to be likely significantly to affect –
>
> (i) the ability of any significant group of animals of that species to survive, breed, or rear or nurture their young; or
>
> (ii) the local distribution or abundance of that species.

European Protected Species (EPS) includes all species of cetaceans (whales, dolphins and porpoise). JNCC (2008) has provided guidance for English and Welsh territorial waters on what constitutes a deliberate disturbance of an EPS. The Habitats Directive Article 12 guidance states "*for disturbance of a protected species to occur a certain level of negative impact which is likely to be detrimental must be involved*". As to what constitutes disturbance, the Commission's guidance states that "*any disturbing activity that affects the survival chances, the breeding success or the reproductive ability of a protected species or leads to a reduction in the occupied area should be regarded as a disturbance in terms of Article 12*". Disturbance defined as "trivial" (sporadic, short-term behavioural reactions) is not likely to be significant and is not likely to result in an offence. For example, JNCC et al. (2010) state that: "*It is most unlikely that a passing vessel would cause more than trivial disturbance. It is the repeated or chronic exposure to vessel noise that could cause disturbance in the terms of the Regulations*".

The Habitats Regulations also requires the designation of sites (Special Areas of Conservation, SACs) for species listed under Annex II. Disturbance within such sites (or in relation to mobile species connected to such sites) is assessed through site-specific information. Marine mammal species included on Annex II are bottlenose dolphin, harbour porpoise, harbour seal and grey seal.

Species

When assessing the impact of disturbance on marine mammal species, it is necessary to understand the purpose of the assessment and therefore which species need to be included. The Environmental Impact Assessment (EIA) process requires the collation of data to identify and assess the potential effects of the development and to identify any significant impacts and any measures envisaged to avoid, prevent or reduce and, if possible, offset, negative impacts. The EIA must consider **all species present** in the vicinity of the development, which have the potential to be impacted by the development. For example, the most common species of marine mammals in Welsh waters that would likely need to be scoped into EIAs include: harbour porpoise, bottlenose dolphin, grey seal, harbour seal, common dolphin, Risso's dolphin and minke whale (Baines and Evans 2012, Evans 2012).

Conversely, **only Annex II species** under the Habitats Directive are required to be included in the HRA process, specifically where SACs have been designated for those species (noting that marine mammals are inherently mobile and the potential for site connectivity is important). All Annex II marine mammal species are noted above, with those that are features of SACs in Welsh waters being harbour porpoise, bottlenose dolphin and grey seal.

Sound types and terminology

This section provides a high-level summary of the key sound types and terminology required to understand the details of the thresholds and sound sources used in this report. The terminology of underwater sound has not been used consistently amongst the literature, and a variety of guidance documents have been developed for underwater noise terminology (e.g. TNO 2011, Robinson et al. 2014, Verfuss et al. 2015). Eventually, ISO guidelines were published in 2017 to ensure an international standardisation for underwater noise terminology in general (ISO 2017). The definitions provided here are mainly directly taken or collated from the guidance documents identified above.

For a comprehensive understanding of the physics of underwater sound, please refer to the literature (e.g. Urick 1983) or the website "Discovery of Sound in the Sea" (DOSITS).

Sound: The term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect. "Sounds" include both meaningful "signals" and "noise" (defined below), which may have either no particular impact or may have a range of adverse effects (Van der Graaf et al. 2012).

Signal: Signal is the sound of interest for the receiver.

Noise: Noise depends on the receiver and the context. What one receiver perceives to be noise may be perceived as a signal to another receiver, and it is possible that the same receiver can perceive the exact same sound to be either signal or noise, depending on the context. Noise can be used in a more restrictive sense where adverse effects of sound are specifically described (Van de Graaf et al., 2012).

Pulses (as defined by Southall et al. 2007): brief, broandband, atonal, transient sounds, which are characterised by a relatively rapid rise-time to maximum sound pressure followed by a decay (that may include a period of diminishing and oscillating maximal and minimal pressure). For example: sounds from explosions, seismic airguns and pile driving.

Impulsive noise (as used in Southall et al. 2019): synonymous to pulses, with the acknowledgement that sound should not be characterised as impulsive or non-impulsive (defined below) based on the source characteristics but on the sound characteristics at the receiver.

Nonpulse (as defined by Southall et al. 2007): intermittent or continuous sound, the sound can be tonal or broadband (or both), and can be short in duration but without the essential proterties of a pulse (e.g., rapid rise-time). For example: vessels, drilling, wind turbines.

Non-impulsive noise (as used in Southall et al. 2019): synonymous to nonpulses.

Sound pressure level: SPL in dB re 1 μPa, which is calculated as twenty times the logarithm to base 10 of the ratio of the **root mean square (RMS)** sound pressure over a stated time interval to a reference value for sound pressure (1 μPa for underwater sound), with RMS sound pressure being the square root of the mean square pressure, where the mean square pressure is the time integral of squared sound pressure over a specified time interval divided by the duration of the time interval.

Peak sound pressure level: $L_{p,pk}$ in dB re 1μPa (also referred to as peak SPL or SPL_{pk}), which is equal to twenty times the logarithm to the base 10 of the ratio of the **peak sound pressure (p_{pk})** to the reference value for sound pressure (1 μPa for underwater sound), with p_{pk} being the maximum sound pressure during a stated time interval.

Peak-to-peak sound pressure level: $L_{p,pk\text{-}pk}$ in dB re 1μPa (also referred to as peak-to-peak SPL or $SPL_{pk\text{-}pk}$),is equal to twenty times the logarithm to the base 10 of the ratio of the **peak-to-peak sound pressure ($p_{pk\text{-}pk}$)** to the reference value for sound pressure (1 μPa for underwater sound), with $p_{pk\text{-}pk}$ being the sum of the maximum sound pressure and the absolute value of the minimum sound pressure during a stated time interval.

Sound exposure level: SEL in dB re 1 μPa²s, which is calculated from ten times the logarithm to the base 10 of the ratio of the sound exposure to a reference value (1 μPa²s for underwater sound). This takes account both the received level and the duration of exposure.

Single strike sound exposure level: SEL_{ss} in dB re 1 μPa²s, which is the total sound exposure level determined for the time period of a single strike (e.g. of a pile strike during offshore wind farm construction).

Cumulative sound exposure level: SEL_{cum} in dB re 1 μPa²s, which is the total sound exposure level determined for an extended period (e.g. 24 hours) or a sequence of pulses/events (e.g. a whole piling sequence during percussive piling during foundation construction at an offshore wind farm).

Third (1/3) octave bands: A frequency band whose bandwidth is one third of an octave.

Frequency weighting: Frequency weighting is analogous to a filtering of sound in the frequency domain. For EIA purposes this is mostly done to account for the frequency-dependent hearing sensitivity of a receptor. Frequency weightings mentioned in this report are from:

- Nedwell et al. (2007): “dBht” use of hearing threshold of a species as an auditory weighting function
- Southall et al. (2007): “M-weighting”: marine mammal group-specific weighting based on human weighting filter designed for high amplitude noise (human C-weighting)
- Southall et al. (2019): Marine mammal group-specific weighting based on estimated group hearing thresholds. Note that National Marine Fisheries Service (2018) present identical weighting curves but different terminology of hearing groups.

Source level: SPL at the source (usually @ 1 m, but also referred to @ 750 m), also used for SEL.

Received level: Sound level at the location of the receiver.

Definition of significant disturbance

A key part of assessing significant disturbance in relation to marine mammals is defining what is meant by the term “significant”. Although all disturbance will be relevant to some extent to a marine mammal, as noted above the legislation requires the potential for significant disturbance to be identified (as it is often a marker for action, for example being the threshold for a disturbance offence). There is no clear single definition of significant disturbance, although a number of guidance documents provide either a definition or key determining factors, with assessment documents providing project specific values of significance. Broad groups for the definition of significant disturbance have been summarised below.

EIA Directive

The EIA Directive (European Union Directive 2011/92/EU, as amended by Directive 2014/52/EU) on the assessment of the effects of projects on the environment, states that “significant” effects should be assessed. The concept of a “significant effect” is complex. The European Commission provided guidance on the preparation of the Environmental Impact Assessment Report (European Commission 2017) where they state: *The concept of significance considers whether or not a Project’s impact could be determined to be unacceptable in its environmental and social contexts. The assessment of significance relies on informed, expert judgement about what is important, desirable or acceptable with regards to changes triggered by the Project in question. This limits the assessment to those impacts that are likely to have a significant or important enough impact on the environment to merit the costs of assessment, review, and decision-making. While the concept of significant effects is referred to several times throughout the EIA Directive, no clear definition is provided, and significance has to be assessed in light of the Project’s specific circumstances*.” (European Commission 2017).

Fixed sound threshold

A fixed threshold in terms of a sound level can be considered a threshold for significant disturbance, with numerous examples of this (see Table 3). Effectively, sound above that threshold would be considered to have the potential to result in significant disturbance to the individual(s) exposed, and can enable the number of individuals thus affected to be calculated. It does not define significance at site level (for HRA) or population level (although it can be used to calculate the percentage of a population affected).

Population level

A Danish document (Anon, 2015) identified a population decline to determine significance, with EPS requirements under the Habitats Regulations having similarities as noted above, for example a disturbance sufficient to affect survival chances. The approach to EIAs can also be similar, such as an ecologically significant adverse effect on a significant number of animals.

Favourable Conservation Status

A negative impact on a species in relation to achieving or maintaining FCS is frequently referenced as a consequence of significant disturbance (e.g. JNCC et al. 2010, ASCOBANS 2014).

Species distribution

SAC management guidance from NatureScot (2020) links significant disturbance to an alteration in distribution of harbour porpoise within a SAC, sufficient to prevent recovery or with long lasting effects (8 years or more), with a similar consideration for EPS requirements under the Habitats Regulations, which links significant disturbance to significant affects on local distribution or abundance of a species.

Habitat Availability

The JNCC et al (2020b) guidance is focused on habitat availability – specifically undisturbed habitat. A significant disturbance is defined through a specified percentage of the habitat within the SAC both on a daily basis and as averaged across a season (6 months). A breach of the thresholds would be deemed adverse (and therefore significant). The thresholds were derived from ASCOBANS, which relate to carrying capacity of the region for harbour porpoise. The German "Sound Protection Concept" (ASCOBANS 2014) is similar, a noise disturbance affecting larger than the defined area would be deemed significant.

Assessment Based

Some guidance identifies factors that can contribute to a given disturbance being assessed as significant. Factors that can be included in the assessment are; change in spatial/temporal distribution of animals, duration of noisy activity, disruption to animal behavioural patterns (e.g.migration, breathing, nursing, feeding, sheltering), learnt behaviour, masking and motivation to remain, suppression of reproductive success, physiological health and long term behaviour (MMPA 1972, NRW 2018, Marine Scotland 2020).

For most EIAs, the significance of an effect is assessed by combining the magnitude of an impact with the sensitivity of the receptor to that impact. As per guidance on methodologies (e.g. PD 6900:2015 Environmental impact assessment for offshore renewable energy projects – Guide (British Standards Institute 2015)), most EIAs will consider the magnitude of an impact together with the importance and value of a receptor and its sensitivity to the impact using a matrix approach such as that shown in Figure 1 (from the Hornsea Project Four PEIR). Here, the Applicant defined a "significant effect" for the purposes of EIA as one that scores Moderate or higher according to the matrix, and therefore minor or lower level of effect was defined as 'not significant' for the purposes of EIA. In this instance, the Applicant stated that: "*The generic methodology… is overarching guidance to enable a more consistent approach and more comparative results within the* *impact assessment. However, EIA remains an expert judgement based on science, expertise and experience*" (Hornsea Project Four PEIR Volume 1 Chapter 5: Environmental Impact Assessment Methodology).

Value, Importance, Sensitivity		Magnitude of Impact/Degree of Change			
		Negligible	Minor	Moderate	Major
	Low	Not Significant	Not Significant or Minor (Not Significant)	Minor (Not Significant)	Minor (Not Significant) or Moderate (Significant)
	Medium	Not Significant	Minor (Not Significant)	Moderate (Significant)	Moderate (Significant) or Major (Significant)
	High	Not Significant	Minor (Not Significant) or Moderate (Significant)	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)
	Very High	Not Significant	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)	Substantial (Significant)

Figure 1 Significance matrix used to derive the Level of Significance of an Impact (taken from Hornsea Project Four PEIR Volume 1 Chapter 5: Environmental Impact Assessment Methodology)

Thresholds used to assess disturbance

There are three key types of threshold that have been used in EIAs and HRAs to assess the potential for disturbance of marine mammals: standard effective deterrent ranges (EDR), fixed noise thresholds and dose-response (D/R) curves. Each of these is summarised below, with information provided on the benefits and limitations of each approach.

Standard effective deterrence ranges

EDR thresholds, as applied in (JNCC 2020b), are area-based thresholds, and are defined by Tougaard et al. (2013) as reflecting the overall loss of habitat that would occur if all animals vacated an area within the range of the EDR, being equivalent to the mean loss of habitat per animal (the average being relevant since more noise-tolerant individuals will lose less than this mean area, while less noise-tolerant individuals would lose more). The approach was then developed for HRA purposes for estimating the potential for temporary habitat loss, to assess the significance of an effect (see **Appendix 4: HRA Guidance**). The approach is directly relevant to many site based conservation objectives, notably those concerned with maintaining access to undisturbed habitat, and with maintaining species range or maintaining access to key habitat.

EDRs are also used in some instances for EIA purposes to obtain number of animals disturbed (see **EIA Thresholds**).

JNCC guidance to assess the significance of disturbance effects in harbour porpoise against SAC conservation objectives provides recommended EDRs for harbour porpoise for a variety of sound sources, including pile driving, UXO clearance and seismic surveys (JNCC 2020c). The German “Sound Protection Concept” (ASCOBANS (2014) included, as an aim, the provision of certainty with regard to injury and significant disturbance. That certainty is implemented through a sound limit at 750 m from source (to prevent injury) and a consequent expectation that the sound limit will result in avoidance/flight behaviour being limited to a range of 8 km from source (based on the assumed attenuation in sound level, with 8 km being the EDR). Further detail is provided in **Appendix 1: Thresholds used for behavioural impact assessment: EDRs** and **Appendix 4: HRA Guidance**.

Benefits and Limitations

The key advantage of this approach is that it is simple to implement as it does not require any site-specific underwater noise modelling to be conducted. That means the method is available to all relevant projects on an equal basis and means management of relevant activities within a designated site (particularly in-combination assessments) is both transparent and relatively easy to implement and manage by a regulator. The approach also focuses attention on key areas of concern (typically in-combination level impacts) and does not attempt to quantify an impact on individuals, something that can be fraught with precaution and uncertainty when the concern is at site level and not population level. This is especially true for sites that may not have a defined population or if a population is understood to be highly mobile, with the JNCC for example considering that it is not appropriate to assign a ‘site population’ to the harbour porpoise SACs. Further, the data that underpins the approach presented by the JNCC (2020c) is derived from field observations of habour porpoise (abundance and distribution) undertaken from a number of similar operations in the North Sea. It is noted that the degree of response varied between projects, with the 26 km value chosen being at the precautionary end of all the ranges available. The German approach is informed through a combination of noise modelling and field data.

All that is required in order to conduct the assessment is to:

- identify the (worst case) location of the sound source (relative to the project location and designated site),
- plot the impact area (circle with a radius of the relevant EDR);
- determine the area of the SACs within the EDR(s) (which might be on a daily/seasonal basis for single or multiple EDRs (excluding any overlap between multiple noise sources within a set time period) and for an assessment alone or in-combination); and
- determine the percentage of the designated site or (in Germany) area of sea that may be affected in terms of area (with significance linked to the 10 % / 20 % thresholds defined by JNCC (2020c) or the 10 % / 1 % advocated in Germany, (ASCOBANS 2014) OR if the assessment is based around individuals extract the number of animals within this area using either a uniform density estimate (density * area) or a spatially explicit density surface (intersect the density surface with the impact area in GIS).

While an individual EDR is fixed, JNCC et al. (2020) advise what sound mitigation at source could mean in terms of a reduced EDR, with the ASCOBANS (2014) paper similarly presenting how the EDR could reduce if the sound level at 750 m from source were reduced further. This method, however, has a series of limitations:

While, on the face of it, an EDR assumes that all receptors within the area of the impact range display a displacement reaction (i.e. there is no dose-response element), as noted above the EDR presented by JNCC (2020c) is based on a mean range of response and assumes that this takes account of the variable level of noise tolerance exhibited at individual level. It is, however, inherently a habitat based approach.

Further, through the application of a standard EDR to the same activity, the approach does not take into consideration variation in location or source level (e.g. UXO detonation has a single EDR regardless of charge size), and instead assumes that the impact range is the same distance from the source irrespective of source level and site-specific environmental conditions. Therefore, it is clear (and acknowledged in JNCC (2020c)) that potential exists on a site by site basis for a smaller (or indeed larger) EDR to be applicable. In practice, thus far the Statutory Nature Conservation Bodies (SNCBs) have requested site based data before consideration would be given to a site based EDR and the authors are not aware of any assessment having been carried out on this basis to date.

A limitation of this approach is the age of the data and number of projects that underpin the EDRs. For example, the JNCC et al. (2020b) guidance recommends a 26 km EDR for the impact piling of monopiles, which was initially proposed in Tougaard et al. (2013) and in JNCC et al. (2020b) is based on evidence presented in Tougaard et al. (2009), Brandt et al. (2011), Brandt et al. (2012), Brandt et al. (2018) and Dähne et al. (2013). Of the references used in JNCC et al. (2020b), the ranges at which a negative effect occurred on harbour porpoise activity and/or harbour porpoise presence varied, being a mean of 17.8 km at Horns Rev II (Brandt et al. 2011), between 10 km and 25 km (Dähne et al. 2013), 12 km at Dan Tysk (Dähne et al. 2017) and >21 km at Horns Rev I (Tougaard et al. 2009). Brandt et al. (2018) reviewed data from 7 of the projects, finding a 50% decline at 10–15 km without noise abatement at source (dropping to 17% with such mitigation), with a clear decline regardless of noise mitigation at source up to 17 km in each case. Therefore, although the evidence base behind the 26 km EDR is dated and based on smaller monopiles than currently being deployed, the range was also established on a precautionary basis. It is not a measure of any or all disturbance / displacement of individuals – rather it represents a conservative area of average habitat loss for all individuals.

Of the references drawn on by JNCC et al. (2020b) for the 26 km piling EDR, these included data from 10 different offshore wind farms. A summary of these projects, together with the sound source levels and pile diameters, are provided below in Table 1.

Table 1 Summary of piling parameters for projects referenced by JNCC et al (2020b) for the 26 km EDR

Project Name	**Pile diameter (m)**	**SEL (dB re 1 µPa²s) measured @ distance**	**Sound mitigation at source?**
Horns Rev	4	Not provided	No
Horns Rev II	3.9	176 @720 m	Assumed not
Alpha Ventus	1.8	167-170 @750 m	Assumed not
Dan Tysk	6	178 @ 750 m	Yes
Bard Offshore I	6	179 @ 750 m	No
Borkum West II	2.5	173 @ 750 m	Yes
Global Tech I	2.6	176 @ 750 m	Yes
Riffgat	6	163 @ 750 m	Yes

Project Name	Pile diameter (m)	SEL (dB re 1 μPa²s) measured @ distance	Sound mitigation at source?
Nordsee Ost	2.4	168 @ 750 m	Yes
Meerwind Süd Ost	5.5	180 @ 750 m	Yes

It is acknowledged that the pile diameters in Table 1 are less than those typically in use at present. For example Sánchez et al. (2019) references an increase in average monopile diameter from 4.85 m in 2009 to 7.26 m in 2018. The recently constructed Triton Knoll has a pile diameter of 7 m, with the consent for Hornsea Project Two (not yet constructed) including monopiles up to 10 m in diameter. From projects currently progressing through planning, it is clear that still larger diameter monopiles are likely. For example, the Hornsea Four Marine Mammal PEIR chapter presented modelled sound levels for 15 m diameter monopiles installed with a 5,000 kJ hammer. Source levels presented were 218.2 - 218.8 SEL_{ss} dB re 1 μPa^{2}s @1m (Hornsea Project Four 2019). Direct comparisons with the sound levels in Table 1 are not possible due to variations in units / range from source and so it should not be assumed that the sound levels presented in Table 1 and Hornsea Four are comparable or that differences in source levels as presented herein would correspond to relative changes in impact range. Tougaard et al. (2013) provides some comparison for the projects considered in that paper, finding '*the SEL values obtained from measurements for a distance of 750 m are typically in the range 172 – 177 dB re 1 μPa^{2}s, whereas the peak-to-peak acoustic pressure levels measured at this distance are in the range 200 – 205 dB re 1 μPa (10 – 18 kPa)*'.

Sound levels emitted during pile driving are (amongst other factors) dependent on hammer energy, and on pile diameter, which is generally smaller for pin-piles than for monopiles, and have been increasing over the last decade due to increasing turbine sizes (Bellmann et al. 2020). Given the age of the data underpinning the EDRs and the gradual increase in size of monopiles since then, it is important that EDRs are regularly updated to take the changing of technology into consideration over time, especially as these larger diameter monopiles are increasingly installed at sea. This was a recommendation made by the Crown Estate with regards to the EDR guidance (JNCC 2020a). Given the need for field measurements to inform the EDRs, such data necessarily follows on after the assessments made based on the older data, hence the importance of precaution in the EDR applied.

It is also important that EDRs are chosen based on a range of studies in a range of environments to be representative. For example, (JNCC 2020b) recommended a 15 km EDR for pin-piles, based on a single study (pin-piles at the Beatrice offshore windfarm in the Moray Firth, Scotland) (Graham et al. 2019), a 15 km EDR for monopiles with sound mitigation at source (Dähne et al. 2017, Rose et al. 2019) and there is no UXO specific data to support the EDR for UXO detonation (in the absence of data it is based on the monopile EDR). Data for the seismic (airgun) EDR is sourced from Thompson et al. (2013a) (a 470 cu inch 2D air gun survey) and Sarnocinska et al. (2019) (a 3D airgun survey), with the 5 km EDR for geophysical survey derived from Crocker and Fratantonio (2016) (measurement of sound from 18 different survey systems) and Crocker et al. (2019) (a programme to quantify characteristics of sound from various survey equipment). It is therefore important to prioritise further studies in order to validate that these EDRs remain appropriate, at all or in various environments.

It is also important to consider that in English, Northern Irish and German water EDRs have only been recommended for harbour porpoise and only for a selected set of sound sources. To our knowledge, there is no equivalent for other key marine mammal species, nor is there inclusion of certain noise sources that can also have disturbance effects (such as shipping, as the JNCC et al. 2020 guidance only applies to regulated activities). Therefore, there is not considered to be a comprehensive set of EDRs for all the relevant sound sources for the key marine mammal species in Welsh and wider UK waters. EDRs for bottlenose dolphin and grey seal would certainly be useful in Welsh waters; however, the practicality and benefit of establishing an EDR for activities that result in a much more localised disturbance (e.g. shipping) is perhaps less clear.

Fixed noise thresholds

Fixed noise thresholds are sound level-based thresholds, where it is assumed that all animals that receive sound above a certain level are disturbed. For EIAs, source- and site-specific underwater noise modelling will be conducted to retrieve contours surrounding the area within which animals are considered to be disturbed. This approach is similar to the way in which instantaneous auditory injury is calculated with thresholds for permanent (PTS) or temporary (TTS) threshold shift (Southall et al. 2007, Southall et al. 2019).

Fixed noise thresholds can be generic (e.g. thresholds based on sound level but are not specific to any sound source or species), sound-source specific (e.g. thresholds specifically for pile driving) or species and sound-source specific (e.g. thresholds for harbour porpoise from airguns). **Appendix 1: Thresholds used for behavioural impact assessment: Fixed noise thresholds** briefly outlines some of the generic fixed noise thresholds that have been adopted for marine mammals. These include:

- NMFS (1995): Harassment Levels (used in US assessments)
- Kastelein et al. (2005): Discomfort threshold
- Nedwell et al. (2007): dBht(Species)
- Southall et al. (2007): Behavioural response criteria (and thresholds derived from these)
- Various TTS-onset Thresholds (used as a proxy for disturbance)
- Lucke et al. (2009): Porpoise adverse reaction threshold
- Tougaard et al. (2015): Avoidance thresholds
- Heinis et al. (2019): Disturbance area threshold

Benefits and Limitations

One benefit of this approach is that the site-specific underwater noise modelling can take into account the effects of source-specific sound characteristics (e.g. level, frequency spectrum and/or impulsiveness of the sound) as well as site-specific environmental variables on propagation. The resulting impact contour from the same sound source can vary both between and within sites. For example, underwater noise propagates further in deeper waters and as such, predicted impact contours at deeper sites will be larger than those for shallow sites. Likewise, if there is variation in depth within an area, then underwater noise from a single source will propagate differently depending on the direction. For example, if there was a deep water canyon in one direction from a noise modelling location then it would be expected that the resulting impact contours would extend to greater ranges in that direction. The fixed noise threshold impact ranges for Dogger Bank Creyke Beck B for low frequency cetaceans illustrate this, with the 142 dB re 1 μPa²s impact contour ranging between ~35 km to >55 km, while the 152 dB re 1 μPa²s contour is rather circular (Figure 2).

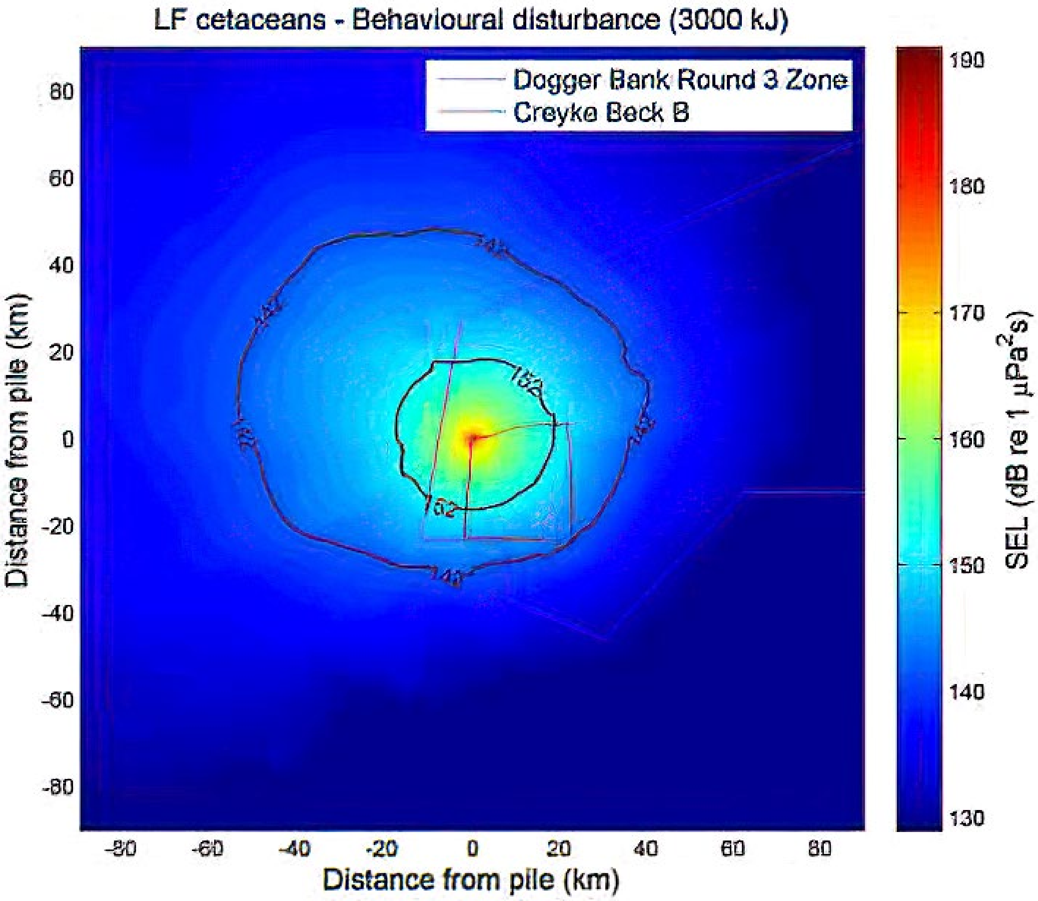

Figure 2 Predicted impact range at Dogger Bank Creyke Beck B using unweighted 152 and 142 dB re 1 μPa²s as fixed thresholds for likely and possible avoidance for low frequency cetaceans (Forewind 2013).

While EDRs are easy to apply to different projects and sites, noise modelling needs to be included as a step of the assessment before the number of animals potentially impacted can be estimated with a fixed noise threshold. The use of a fixed noise threshold assumes that all receptors within the area of the threshold's calculated impact range display a behavioural reaction, while none of the receptors outside this area will react. There is no evidence to support this assumption. However, there may be a balance between the animals that do not react within the calculated impact area and those that are affected outside the range.

Another limitation of the fixed noise thresholds is that they are based on the different authors' assumptions to which metric of the sound animals reacts to, leading to a variety of threshold-metrics. NMFS (1995) are based on unweighted SPL values, while Nedwell et al. (2007) use a frequency weighted approach. Southall et al. (2007) divide their thresholds into species group specific and furthermore sound characteristic specific thresholds, leading to a variety of different unweighted sound metrics. In the absence of any supporting study-results Southall et al. (2007) furthermore suggest to use weighted TTS-thresholds for single pulses.

While most recent behavioural thresholds are based on unweighted metrics, Tougard et al. (2015) propose and present some evidence for harbour porpoise that a weighted threshold based on the species' hearing threshold might be appropriate to use. Weighted thresholds would allow the use of species- or species group specific thresholds that can be used for different sound sources, similar to the recent approach used for the auditory injury noise impact assessment (National Marine Fisheries Service 2018, Southall et al. 2019). This would also influence decisions when considering noise abatement systems (Verfuss et al. 2016, Tougaard and Dähne 2017). How this approach should be implemented is debated amongst experts (Energinet.dk 2015a) and while it is reasonable to assume that a weighted threshold would provide a better behavioural response prediction than an umweighted one, there is yet no consensus due to limited data availability (De Jong et al. 2019).

Dose-response curves

Dose-response (D/R) curves are based on the assumption that not all animals in an impact zone will respond. Therefore, the probability of a response, and thus the proportion of animals experiencing behavioural disturbance, will depend on a "dose" it perceives. As for the fixed noise thresholds, the dose of curves can be given in different metrics. The dose can either given as the distance from the sound source or the received weighted or unweighted sound level at the receiver. It is currently unknown whether it is distance from the source or the received levels of sound or a combination/interaction of these that best predicts the probability of response. The probability of response can be measured by a decrease in density or sightings rate in response to a sound source, by a decrease in detected vocalisations in response to a sound source or through individual based movements from tagged animals (e.g. Brandt et al. 2013, Russell et al. 2016, Graham et al. 2019).

D/R curves have typically been determined as a result of controlled exposure experiments and individual based studies such as focal follows and tagging studies. Most of the literature on this subject is for large whale species in response to naval sonar; a review of which is provided in Harris et al. (2018). Many of the D/R curves that are available in the literature are for species that are not of relevance for impact assessments in Welsh waters, such as killer whales (Miller et al. 2014), long-finned pilot whales (Antunes et al. 2014), sperm whales (Harris et al. 2015), humpback whales (Sivle et al. 2015) and beaked whales (Moretti et al. 2014). However, there is now growing literature on dose-response curves for UK species (harbour porpoise and harbour seal) in response to pile driving (e.g. Graham et al. 2019, Whyte et al. 2020) (see **Appendix 1: Thresholds used for behavioural impact assessment: Dose-response curves**).

The use of D/R curves is not recommended for area-based assessment in an HRA for harbour porpoise SACs; 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 harbour porpoise spatial/temporal thresholds for HRA are not concerned with numbers of animals.

Benefits and Limitations

Compared to the EDR and fixed noise threshold approaches, the application of a D/R curve allows for more realistic assumptions about animal response varying with dose, 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. For example, the harbour porpoise D/R curve for pile driving (Figure 3) predicts >90% response at received levels of 160 dB re 1 μPa^{2}s SEL_{ss}, ~70% response at 150 dB re 1 μPa^{2}s SEL_{ss} and only ~50% response at 145 dB re 1 μPa^{2}s SEL_{ss}. Therefore the assumption that 100% of the animals are disturbed within the fixed 145 dB re 1 μPa^{2}s SEL_{ss} threshold (Lucke et al 2009) is likely highly over-precautionary compared to the evidence underpinning the D/R curve. However, as the 145 dB re 1 μPa^{2}s SEL_{ss} threshold is missing animals that respond at distances beyond the threshold, there will be some balancing within this estimate.

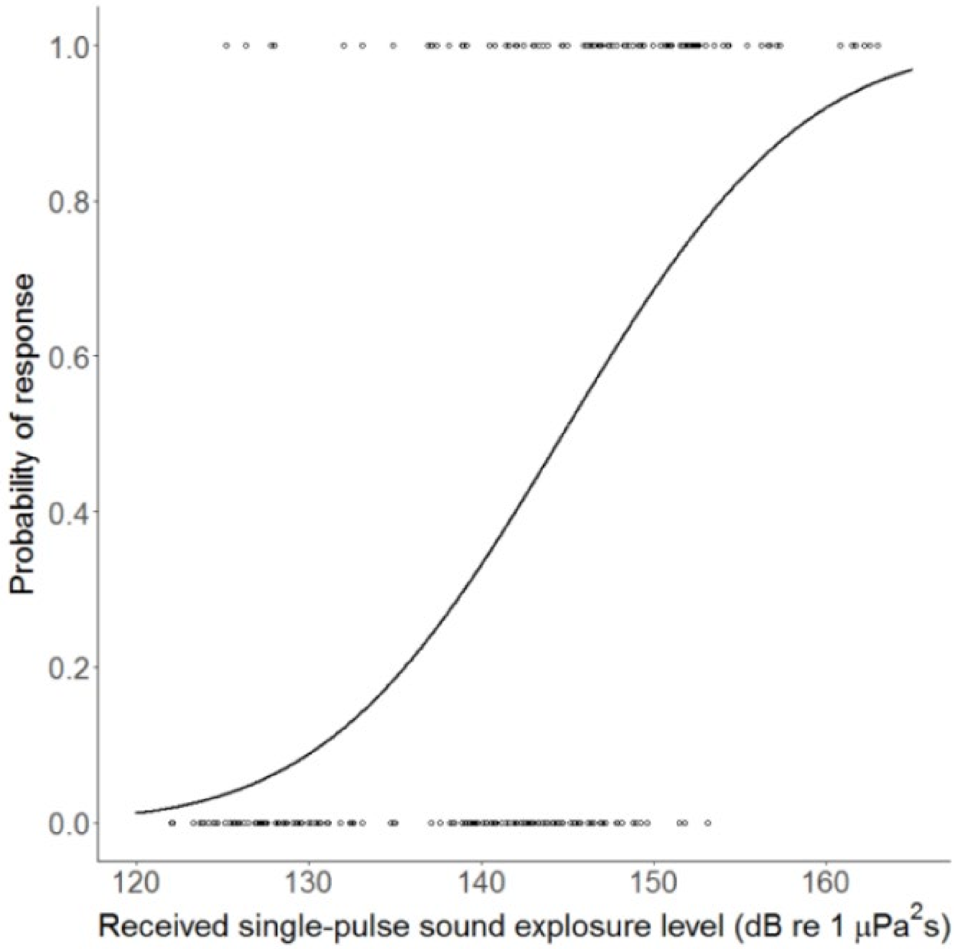

Figure 3 The probability of a harbour porpoise response in relation to received single-pulse SEL (Graham et al. 2017).

Computationally, the use of a D/R curve in a quantitative noise impact assessment is more complex and time consuming compared to EDRs and fixed noise thresholds, since it requires that multiple noise contours are modelled for one sound source. For example, the harbour porpoise D/R curve adopted in recent offshore windfarm EIAs provides varying level of response between 120 and 180 dB re 1 μPa²s SEL_{ss}, this is usually presented at 5 dB intervals, which results in the modelling and processing of 13 impact contours for a single sound source at a single location (e.g. Figure 4).

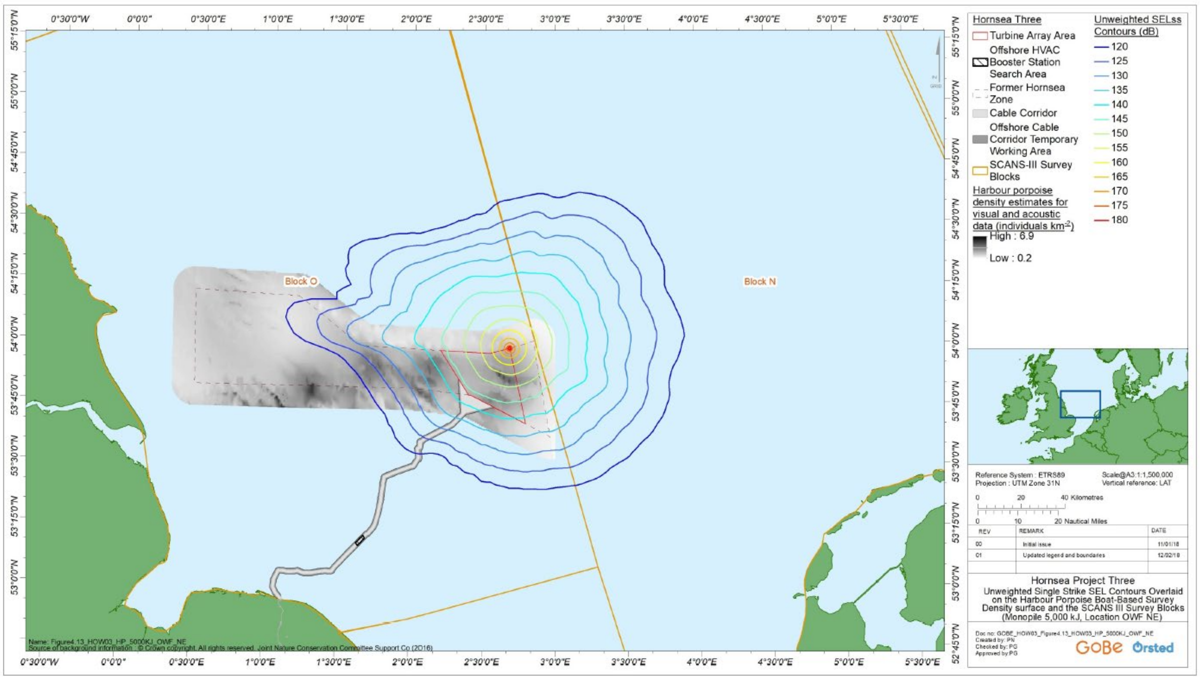

Figure 4 Unweighted single-strike SEL contours overlaid on the harbour porpoise boat based survey density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location Hornsea Three NE) (Orsted Hornsea Project Three (UK) Ltd 2018).

D/R curves with distance as the dose are easy to apply to different regions and situations, similar to EDRs. However, there are challenges in using a D/R curve based on distance that has been created for one site, as it may well not be transferrable to other sites if the sites differ in, for example, bathymetry and sediment type, as this would affect the transmission of sound through the water. Similarly, the distance-based D/R approach is unlikely to be representative if used to assess the impact from a source with a different source level – a higher (louder) source level will result in larger impact ranges, and therefore the dose-response curve derived from the lower source level would underestimate impact ranges.

When applying D/R curves with received levels as dose, it is sensible to take the background noise levels at the site into consideration when deciding on the lowest isopleth to be included into the analysis. For example, the harbour porpoise D/R curve (Figure 4) predicts low level response probabilities down to 120 dB re 1 μPa²s SEL_{ss}, which may be at or below the background noise levels in noisy areas with SPLs at or exceeding 120 dB re 1 μPa SPL, e.g. those of high shipping densities (Farcas et al. 2020). To be at level with the background noise, the duration of the dose-signal would need to be close to or exceeding 1 second so that an SEL of 120 dB re 1 μPa²s would mathematically be around or below an SPL of 120 dB re 1 μPa. The study of Hastie et al. (2019) shows that the duration of impulsive noise from pile driving and seismic survey generally increase with increasing distance to the sound source and may well be near or above a duration of 1 second. This simplified way of checking if the dose-signal will be masked by the background noise will, however, only work for signals that are in the same frequency range as that the background noise is composed of (usually within the low frequency range) as higher frequencies signals may still well be above the low frequency background noise level despite having the same broadband SPL.

The most convenient way of ensuring that the analysis of a D/R curve dose does not consider isopleths below background noise would be a recommendation for future studies to calculate maximum SPL values of the dose next to other relevant noise measures, as well as to characterise the frequency spectrum of the dose-signal. This limitation may also apply to fixed thresholds of a low broadband SPL value (e.g., NMFS 1995, Level B harassment for non-impulsive sound). This would result in a low signal:noise ratio which would mean that the sound would be masked by the ambient noise and therefore inaudible to the receiver. As such, when applying the D/R curve it is important to consider the background noise levels at a specific site and up to which noise contour sound from the source would be audible to the receiver. If this is not taken into consideration then impact assessments may well overestimate the disturbance impact.

As noted above, D/R curves for pile driving exist for both harbour porpoise and harbour seal in UK waters (see **Appendix 1: Thresholds used for behavioural impact assessment: Dose-response curves**). However, there are no equivalent curves for other key UK species such as grey seal, bottlenose dolphin or minke whale. Some EIAs have used the harbour porpoise D/R curve for all cetacean species and the harbour seal D/R curve for grey seal. This approach has its limitations given the different hearing ranges and sensitivities between the species, particularly in the case of minke whale. However, it is considered that harbour porpoise (very high frequency cetaceans) are likely to be more sensitive to underwater noise than dolphin species or minke whale (high or low frequency cetaceans). Therefore, by applying a D/R curve from a more sensitive species, to a less sensitive species is likely to result in overestimates of disturbance which, while not ideal, is at least a precautionary approach. However, one has to consider that the sound energy of pile driving is highest in the low frequency range, and overlaps more with the hearing range of a minke whale than with that of a harbour porpoise. In other words, pile strikes of the same unweighted SEL_{ss} are louder for a minke whale than for a harbour porpoise. Tougaard et al. (2015) therefore recommend the use of weighted SEL to investigate behavioural reaction. Some received level D/R curves are based on weighted thresholds (e.g. dBht) while others are based on unweighted thresholds (e.g. SEL_{ss} – see **Appendix 1: Thresholds used for behavioural impact assessment: Dose-response curves**). Those based on unweighted thresholds may well be transferable to other situations when considering the same species and a sound source with similar noise emission. Using species-specific frequency weighting may allow a generalised use of a D/R curve obtained from one species (e.g. harbour porpoise) and a specific sound source (e.g. piling), in order to use it for another species (e.g. minke whale) and/or another sound source (e.g. ADD). This would be done under the assumption that the behavioural response correlates with the loudness of the sound (the sound level an animal can sense) and is independent from species and shape of the sound. Tougaard et al. (2015) presents examples supporting this assumption. All in all, when using a D/R , one has to make sure that it is applied correctly to the investigated scenario by choosing the correct dose-unit.

Summary of benefits and limitations

The summary below provides a high level comparison of the key benefits and limitations of the various disturbance assessment methods available (EDR, fixed noise threshold, dose-response (distance and received level). No method is without limitations and the degree of uncertainty surrounding the results of an assessment done for a specific project at a certain site, for a specific species and/or sound source differs with each method and/or threshold chosen.

There are considerable limitations with the process of using the results from one specific study, on one specific species in one specific location to one specific sound source to create a threshold for use in future assessments. As such, caution should be applied to thresholds that have been derived in such a way. Where thresholds have been proposed by authors and regulators (e.g. the Southall et al. 2007 TTS, PTS and proposed behavioural response thresholds), they should ideally and where available be based on detailed review studies of the available literature, taking into consideration the range of evidence and the uncertainty in the response. Therefore it is highly recommended that any threshold (EDR, fixed noise threshold or D/R curve) is derived from a range of representative sites and sources in order to be taken forward as a generalised threshold to other sites for impact assessment. As the technology used in offshore activities and developments changes over time, it is imperative that they are monitored in order to update the thresholds to ensure that they are representative for current and future impact assessments.

One key source of debate in the scientific community at present is the use and application of auditory time and frequency weighting when deriving behavioural thresholds. Recommended thresholds for auditory injury (PTS and TTS) are based on SEL_{cum} that is weighted according to species groups (see Southall et al. 2019 for detail on auditory weightings for marine mammals). However, the use of auditory weighting functions in behavioural thresholds is less well understood, as is the noise exposure metric that is best suited to assessing behavioural reactions. For the assessment of behavioural disturbance from single pulse sources,Southall et al. (2007) recommended both weighted SEL and unweighted $L_{p,pk}$ metrics (see Table 7). This is reviewed in detail in Tougaard et al. (2015), where the authors argue that the weighted SPL of a signal is likely to be a good proxy for the loudness of the signal and is conjectured to be a predictor of behavioural response of marine mammals.

Approach: Effective deterrence range

Benefits

- Simple assessment
- Can be used to assess potential for significant disturbance alone/in-combination for HRA
- Useful site management tool especially in-combination
- Can be applied in the absence of population data and noise modelling
- Based on observed/recorded behavioural response of animals

Limitations

- Unrealistic assumptions about animal response
- No consideration of noise propagation and source characteristics
- Lack of or limited supporting evidence for some EDRs
- Aged supporting evidence for some EDRs

- Does not take into account variation in species density/hotspots
- Not directly transferable to noise threshold values
- Not available for all marine mammals or all types of sound source

Approach: Fixed noise threshold

Benefits

- Considers site-specific noise propagation and source characteristics

Limitations

- Unrealistic assumptions about animal response
- May be species-specific or sound source specific, and therefore transferability to other species and/or sound sources may be questionable

Approach: Dose-response (distance)

Benefits

- Considers site-specific noise propagation and source characteristics
- More realistic assumptions about animal response

Limitations

- Cannot be applied to area-based assessment thresholds for harbour porpoise SACs
- Complex assessment
- Lack data for most species & sound sources
- Specific to species, study area and source characteristics: limited transferability?

Sound sources assessed in relation to disturbance

This section provides a high level summary of the different sound sources typically assessed for marine mammals, the sound characteristics of the different sound sources and the level of evidence available for each of the key species in Welsh waters. **Appendix 2: Sound Sources** provides more detailed summaries, including references.

In general, there is good evidence of disturbance response for the key species found in Welsh waters to vessels and impact pile driving, where responses vary from changes in individual swimming and diving behaviour to changes in distribution. For other sound sources, there is considerably less evidence, if any at all. This makes it very difficult to define a disturbance threshold for many species and sound source combinations as there simply isn't the scientific data available.

Vessels

Main characteristics: Non-impulsive, continuous. Frequency can vary considerably: mainly low frequency range between 10-100 Hz; however, noise is also generated at higher frequencies (tens of kHz).

Species info

- **Harbour porpoise**: Good evidence: change in distribution, change in vocalisations, change in dive behaviour, reduced foraging, erratic behaviour etc.
- **Bottlenose dolphin**: Good evidence: changes in swimming behaviour, reduction in resting and socialising, reduction in foraging. Evidence of different levels of response between locations.
- **Grey seal**: Lack evidence of disturbance at sea. Overlap between high vessel areas and grey seal activity.
- **Common/Risso's dolphin**: Some evidence: changes in behavioural state, disruption of foraging and resting, reduced presence.
- **Minke whale**: Few studies but some evidence of decreased foraging and increased energy expenditure.

Dredging

Main characteristics: Non-impulsive, continuous. Broadband - frequency and SPL varies. SPL SL 172-190 dB re 1 μPa. Frequency range 45 Hz to 7 kHz.

Species info

- **Harbour porpoise**: Some evidence of short-term avoidance
- **Bottlenose dolphin**: Some evidence of reduction in presence
- **Grey seal**: No evidence
- **Common/Risso's dolphin**: No evidence
- **Minke whale**: No evidence

Drilling

Main characteristics: Non-impulsive, continuous. Low frequency. Fundamental frequency at 125 Hz, harmonics up to 8 kHz.

Species info: None for key Welsh species.

Seismic

Main characteristics: Loud, impulsive. Received $L_{p,pk\text{-}pk}$ of 165–172 dB re 1 μPa have been recorded, and SEL may range from 145–151 dB re 1 $\mu Pa^2 s$ (Thompson et al. 2013a). Low frequency. Main energy around 200 Hz, higher frequencies of 10 kHz can also produced.

Species info

- **Harbour porpoise**: Variable between surveys. Change in vocalisations (assumed displacement).
- **Bottlenose dolphin**: Limited: displacement and changes in swimming
- **Grey seal**: Limited: Detection rates lower
- **Common/Risso's dolphin**: Limited: change in swim speed and reduction in presence
- **Minke whale**: Limited: reduction in presence.

UXO

Main characteristics: Very loud, impulsive. Depends on charge weight. SEL can be above 223.5 dB re 1 μPa^{2}s. Low frequency centred around 1 kHz.

Species info

- **Harbour porpoise:** No evidence.
- **Bottlenose dolphin**: Limited.
- **Grey seal**: No evidence.
- **Common/Risso's dolphin**: No evidence.
- **Minke whale**: Limited.

Piling

Main characteristics: Very loud, impulsive. Very high source levels (up to $L_{p,pk-pk}$ SL of 250 dB re 1 μPa).

Species info

- **Harbour porpoise**: Good evidence: displacement, change in swimming behaviour, change in dive behaviour.
- **Bottlenose dolphin**: Limited: reduction in presence.
- **Grey seal**: Limited: large variability between individuals, change in swimming and diving behaviour, reduction in foraging.
- **Common/Risso's dolphin**: No evidence.
- **Minke whale**: No evidence.

Wave and Tidal device

Main characteristics: Low frequency, tonal sound, with harmonics up to 2 kHz (Risch et al. 2020).

Species info

- **Harbour porpoise**: Limited: reduced presence.
- **Bottlenose dolphin**: Limited: reduced presence.
- **Grey seal**: No evidence.
- **Common/Risso's dolphin**: No evidence.
- **Minke whale**: No evidence.

Review of methods used for EIA

This section provides a high-level summary of the approaches that have been used in recent impact assessments, primarily in UK waters. Included in this section are the definitions of magnitude and sensitivity used to assess the significance of an impact, the thresholds used to assess disturbance and the approaches undertaken to identify population level effects.

EIA approaches of different countries

In the following, the UK approach is described in most detail, and will be complemented by high level information mostly considering offshore wind farm construction, as this is the area where most information is publicly available (in English).

UK

The key policy and legislation that is considered in marine mammal impact assessments in UK waters include:

- EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive)
- Conservation of Habitats and Species Regulations 2010 (in relation to reserved matters) and the 1994 Regulations
- Offshore Marine Regulations
- Wildlife and Countryside Act, 1981
- Conservation of Seals Act, 1970
- National Policy Statements

Most of which describe the requirements to conserve and protect species from killing, injury and **disturbance**. The Habitats Regulations and the Offshore Marine Regulations make it an offence to injure any EPS. An incident of disturbance could be considered an offence if the disturbance is likely to have an ecologically significant adverse effect.

Under the Planning Act 2008, all Nationally Significant Infrastructure Projects (NSIPs) within England and Wales are submitted to the Planning Inspectorate. NSIPs are major infrastructure projects, including offshore wind farms. Submission of the Developers application to the Planning Inspectorate (in the form of an Environmental Statement) means that the application documents become publicly available on the National Infrastructure Planning website. This includes all large-scale developments (relating to energy, transport, water, or waste), including offshore windfarms and harbour developments in English and Welsh waters. Therefore, NSIPs have a clear route for environmental assessment, consenting and tracking, and it is easy to obtain a copy of the EIA for a proposed offshore windfarm or harbour development via the National Infrastructure Planning website.

Conversely, applications for oil and gas related activities are submitted by Operators to the Department of Business, Energy & industrial Strategy (BEIS) via the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) PETS portal (Portal Environmental Tracking System). This portal integrates applications through the Master Application Template ('MAT') for a variety of oil and gas related activities including drilling, well intervention, pipeline operation and seismic surveys. As part of the MAT submission, the operator is required to upload an EIA. However, these MAT submissions are not publicly available, and as such, it is difficult to obtain a copy of EIAs related to oil and gas activities submitted e.g. in England & Wales to BEIS OPRED. Additionally, the process is less well defined for other offshore noise generating activities such as underwater acoustic surveys some of which are unregulated (e.g. seismic surveys that do not fall within the Petroleum Act or Energy Act regime) (Hartley Anderson Ltd 2020).

Overall this means that while it is a simple process to obtain a copy of an EIA for an offshore windfarm, wave and tidal project or harbour development, it is much more difficult to obtain a copy of an EIA for activities related to the oil and gas industry and other acoustic survey operations. As such, this review of disturbance methods is more focused on the disturbance impacts predicted for offshore developments.

Most quantitative underwater noise impact assessments for UK projects follow the same structure and approach:

- Baseline characterisation – identify species, management unit and density
- Definition of magnitude of impact & sensitivity of receptors
- Quantitative impact assessment – use species density and impact area to obtain number of animals impacted
- Population modelling (usually only if impact is deemed to be significant).

In the UK, the EIA process provides an assessment of the maximum design scenario for the worst-case impact pathway(s). Therefore offshore windfarm EIAs tend to only provide a full quantitative impact assessment for underwater noise for pile driving construction activities (as this is the impact pathway that is expected to produce the most impact) and not for other noisy activities such as drilling, cable laying etc. For example, the Burbo Bank Extension EIA (DONG Energy 2013) modelled the predicted impact ranges for harbour porpoise using the 90 dBht threshold for various underwater noise sources associated with offshore windfarm construction and operation (Figure 5). This modelling clearly showed that impact ranges for impact piling were considerably larger (~13 km) than for other activities (up to 140 m) and therefore impact piling was taken forward as the main construction related activity for a full quantitative impact assessment (predicting number of animals disturbed etc) as it had "*by far the greatest impact on marine mammals*" and since "*piling is widely accepted as being the major source of anthropogenic noise associated with the construction of an offshore wind farm, …it is predicted that any impacts from cable laying/trenching will be indistinguishable from those for piling*".

Since there is no recommended guidance on the methodology that should be applied when assessing behavioural disturbance to marine mammal species in the UK, the methodology used in EIAs has evolved over time as new scientific knowledge has been gathered. As described above, the assessment of disturbance from pile driving has evolved from early EIAs that adopted the generalised Level B harassment fixed noise threshold (from the USA) for all species, to EIAs that used species specific fixed noise thresholds such as dBht to more recent EIAs that have adopted a dose-response approach.

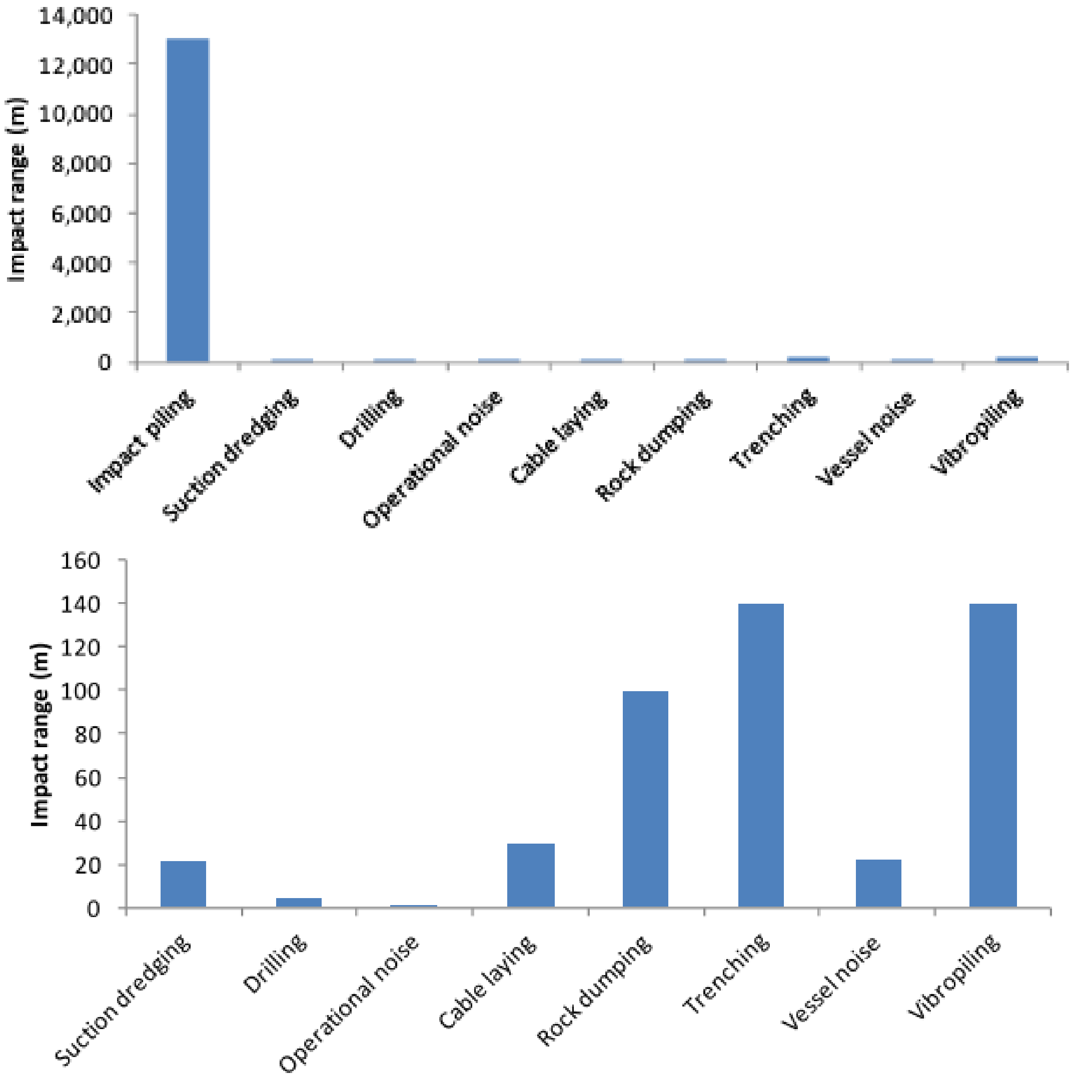

Figure 5 Predicted impact ranges for harbour porpoise for various modelled offshore activities using the 90 dBht criteria (above: including impact piling, below: excluding impact piling) (figure taken from DONG Energy 2013).

Germany

Similar to the UK to date, marine mammal impact assessments in Germany have to consider the EU Habitats Directive and various national laws (including those that implement the Habitats Directive). Depending on the activity and its location within German waters, different authorities are responsible for the licensing procedure. For example, the Federal Shipping and Hydrographic Agency (BSH) is responsible for the approval process of wind turbines and building structures in the German Exclusive Economic Zone. Applicants have to conduct and submit the relevant impact assessments. The approval process for mining, exploration and production within territorial waters of the Federal States of Lower Saxony and Schlesswig-Holstein, as well as the EEZ, is the Federal Agency for Mining, Energy and Geology (LBEG).

Similar to the assessments in the UK, German EIAs include a baseline characterisation of the identified species. In the frame of the expansion of offshore wind farms in the German Exclusive Economic Zone, baseline monitoring is mandatory and standardised (Aumüller et al. 2013), resulting in a valuable set of data from strategic monitoring, which EIAs can base their assessment on. Similar to the UK, evaluation matrices are used for assessing the impact of the noise associated with anthropogenic activities. In contrast to the UK, neither a quantitative impact assessment nor subsequent population modelling is conducted, at least for offshore windfarm applications. This is due to mandatory compliance with noise protection measures in the form of impulsive noise thresholds that are not to be exceeded. These thresholds have been mandatory in BSH approval notices since 2008, and are defined as a dual criterion. The thresholds of **160 dB re 1 μPa²s SEL_{ss} and 190 dB re 1 μPa SPL_{peak} must not be exceeded at a distance of 750 metres from the piling site**. The thresholds arose from the first study on the onset of TTS in harbour porpoise, the key species in German waters (Lucke et al. 2008, 2009). Based on the results of this study, a noise threshold was introduced considering TTS as auditory injury, which is to be avoided at any time. EIAs with noise predictions above these thresholds for impulsive noise therefore have to propose mitigation measures such as noise-reduction systems (e.g., hydrosound dampers or bubble curtains, or a combination of such systems, as described in Verfuss et al. (2019), Bellmann et al. (2020)). Noise-reduction systems also need to be used during UXO detonation.

The behavioural impact assessment of impulsive noise is usually based on a **SEL_{ss} threshold of 140 dB re 1 μPa²s** as proposed by the Sound Protection Concept (ASCOBANS 2014), and with it a maximum **EDR of 8 km** (for details see **Appendix 4: HRA Guidance**). No common non-impulsive noise thresholds exist and non-impulsive noise (e.g. from ship traffic or other constructions) are generally discussed in a rather qualitative manner in EIAs.

Denmark

In Denmark, the Danish Energy Agency (DEA: Energistyrelsen) is the regulating agency for offshore wind farms. The focus on underwater noise was limited in the first Danish offshore wind farm EIAs, but increasing foundation size and associated increasing noise levels lead to concerns over the impact on marine wildlife, especially for harbour porpoise. Therefore, Energinet.dk formed a working group in order to create a concept on how to regulate underwater noise. A set of auditory injury thresholds for harbour porpoise and harbour seal, and a behavioural threshold for harbour porpoise (**SEL_{ss} 140 dB re 1 μPa²s**) were established (Energinet.dk 2015a) along with proposals on how to conduct impact assessments (for details see **Appendix 4: HRA Guidance**).

Based on these recommendations, site-specific impact assessments have been conducted for six Danish Offshore Wind farms, of which the results are presented in Energinet.dk (2015b). The main focus of the EIA was the calculation of PTS impact ranges to understand the options for mitigation measures to minimise the risk of PTS. Based on the resulting final scenario, behavioural impact ranges and number of animals disturbed were estimated. The EIA consisted of fleeing animal noise modelling to estimate auditory injury impact ranges for an average and worst-case scenario based on the expected transmission loss in the area. Modelling was conducted with the animal starting to flee at different distances (1 m, 1 km, 2 km). The cumulative SEL was estimated and compared with the PTS noise threshold to understand which combination of mitigation measures (ADDs and/or noise reduction systems) would be needed to reduce the number of animals experiencing PTS to zero. Using site-specific density estimates informed by current literature, the number of animals potentially disturbed or experiencing auditory injury were calculated for each of the different scenarios. The implications of the number of animals disturbed were not discussed further. For further details see **Appendix 4: HRA Guidance**.

Netherlands

In the Netherlands, the Netherlands Enterprise Agency (RVO) organizes the application procedure (tender) for permits for new wind farms (as outlined on their website). The elaboration of the relevant thresholds for behavioural impact have been the responsibility of the Dutch government. Rijkswaterstaat agreed to develop an 'Ecology and accumulation of effects assessment framework' for Round 3 offshore wind energy. As part of that process, an Underwater Sound Working Group was established that determined the cumulative effects of impulsive underwater sound on relevant populations of marine mammals in the North Sea, resulting in the first "Framework for Assessing Ecological and Cumulative Effects" (Kader Ecologie en Cumulatie: KEC) (Heinis et al. 2015). This assessment included impulsive noise expected from the offshore wind farm areas planned from 2016 to 2023 as well as seismic surveys. The main focus was on the possible effects on the harbour porpoise population in the Dutch Continental Shelf. No more than 5% of the Dutch harbour porpoise population was to decline as a result of the construction of offshore wind farms up to 2023 with a high degree of certainty (95%). Population modelling with iPCoD supported the decision on threshold values for the different wind farm areas, which were based on "animal disturbance days". These express how many animals can be disturbed per year depending on the number of piling days, season and duration of the disturbance per piling day. For the calculation of how many animals will be disturbed by a piling activity, a **fixed noise threshold value of 140 dB re 1 μPa²s SEL_{ss}** was used (Heinis et al. 2015). With the adoption of animal disturbance days, a rather flexible threshold was chosen, which allowed the freedom for a developer to choose either fewer foundations with bigger pile diameters (and therefore louder piling noise) or more foundations with smaller pile diameters or the use of noise reduction systems to allow for more piling days.

In order to accommodate the further expansion of offshore wind farms in Dutch waters, the KEC was updated for the period of 2023 through to 2030. This time, a mandatory noise limit was defined to keep the number of animals disturbed below the threshold that would cause significant changes to the population level (as described above). With the application of the same behavioural fixed threshold as used in the previous KEC, the resulting mandatory noise limit came to **168 dB re 1 μPa²s SEL_{ss}** (Heinis et al. 2019). An update of the KEC is currently planned for developments from 2030 onwards (de Jong, pers comm. 25.03.2021).

EU

The cumulative impact of OWF pile driving in the North Sea on the harbour porpoise population has been modelled as part of a common environmental assessment framework (CEAF) in the frame of a cooperation project 'Strategic Environmental Assessment North Sea Energy (SEANSE)' as an aid for Maritime Spatial Planning of the North Sea countries (De Jong et al. 2019). The modelling was conducted with iPCOD (see **EIA population consequences** for details). For the population modelling the number of harbour porpoises disturbed was calculated, obtained by modelling the impact range around a piling site using a behavioural threshold and using a local density estimate. To quantify the effect of piling on the population, the number of 'harbour porpoise disturbance days' was defined, which is the number of disturbed animals per day multiplied by the number of days they are disturbed. While the description of this project and its outcome of it is out of scope for this report, two comparisons made in the report from De Jong et al. (2019) are interesting to highlight in the current report:

1) They showed examples of noise modelling at two piling locations, one in Dutch waters and one in British waters. While piling in Dutch waters must adhere to a noise limit, it does not in UK waters. Figure 6 shows the difference between the sound field around the piling sites and the behavioural impact area based on a **fixed threshold value of 140 dB re 1µPa²s**. This comparison makes clear how much the resulting impact area depends on differences in the initial sound levels at or near the source as well as bathymetry (see also **EIA examples**).

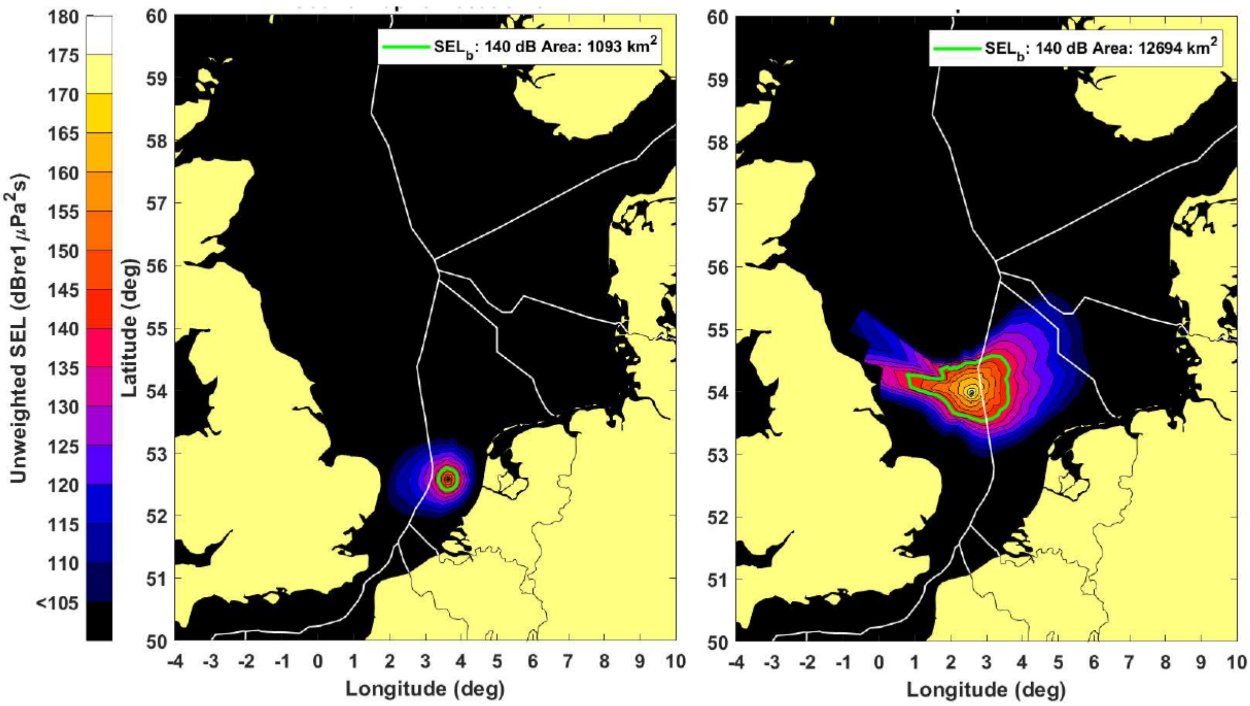

Figure 6 Examples of sound maps (left: Hollandse Kust (West II) and right: Hornsea Project Three) with contours in green for the sound levels at which the limit value of 140 dB re 1 µPa²s for disturbance of harbour porpoises is exceeded. Mitigation of piling sound (left panel; noise limit SEL_{ss}(750 m) = 168 dB re 1µPa^{2}s) results in a much smaller disturbance area than unmitigated piling (right panel). The asymmetric shape of the disturbance area in the right panel is caused by the bathymetry. Taken from De Jong et al. (2019) (Figure 2).

2) The authors calculated the number of harbour porpoise disturbance days for each of the North Sea countries based on offshore wind farms expected to be in operation from 2023 to 2030 plus those developments expected to take place after 2030 as far as already identified by the governments of the participating countries at the time of collating the information for that specific project. De Jong et al. (2019) then compared the resulting number of harbour porpoise disturbance days calculated based on a) the **fixed threshold of 140 dB re 1µPa²s** while considering respective noise limits existing at that time in Dutch and German waters, and b) an **EDR of 26 km**. The resulting number of harbour porpoise disturbance days are quite different from each other, especially when considering UK waters (Table 2).

Table 2 Number of piling days expected in the different North Sea countries based on offshore wind farms considered to be operational from 2023 onwards, and the corresponding harbour porpoise disturbance days calculated based on either a fixed threshold of 140 dB re 1μPa²s or the use of an EDR of 26 km (adapted from: De Jong et al. (2019)).

Country	Piling days	Harbour porpoise disturbance days: Fixed threshold	Harbour porpoise disturbance days: EDR
BE	344	51,247	437,998
FR	63	31,780	82,782
DK	173	10,642	99,778
DE	1,866	644,497	2,732,532
NL	1,590	1,503,368	2,122,983
UK	2,609	22,154,369	3,751,298
Total	**6,645**	**24,395,903**	**9,227,371**

USA

All marine mammals in waters of the United States of America are protected under the Marine Mammal Protection Act (MMPA). The MMPA probibits the "take" of marine mammals, where "take" includes **harassment**, hunting, capturing, collecting, or killing. The MMPA defines harassment as any act of pursuit, torment, or annoyance which (1) has the potential to injure a marine mammal or marine mammal stock in the wild (Level A harassment); or (2) has the potential to **disturb a marine mammal** or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B harassment). Impact assessments in the USA assess the potential for offshore activities to disturb marine mammals, using the Level B harassment threshold of **120 dB re 1 μPa rms (for continuous noise) and 160 dB re 1 μPa rms (for impulsive noise)**. This is ubiquitous across the US impact assessments we reviewed.

New Zealand

In 2013, the Department of Conservation (2013) released a Code of Conduct to minimise the acoustic disturbance to marine mammals from seismic survey operations. This Code provides two critical levels of sound in water:

- The level of sound likely to result in injury = 186 dB re 1 μPa^{2}s
- The level of sound likely to result in a **significant behavioural response = 171 dB re 1 μPa^{2}s**

which were derived from the evidence presented in Southall et al. (2007). In New Zealand, the sound levels produced by seismic activity must not exceed 171 dB re 1 μPa^{2}s within

- the 200 m mitigation zone for marine mammal species not designated as a Species of Concern (e.g. New Zealand fur seal, common dolphin, dusky dolphin)
- the 1 km mitigation zone for Species of Concern (full list please see schedule 2 of this pdf document)
- the 1.5 km mitigation zone for Species of Concern with a calf

A list of the marine mammal Impact Assessments that have met the standards described in the Seismic Code of Conduct to the satisfaction of the Director-General of the Department of Conservation are listed on this website. While no code of conduct for marine mammals has been provided by the Department of Conservation for any other sound source, pile driving companies tend to work towards the seismic survey code of conduct as the two activities are considered to have similar sound characteristics.

EIA Thresholds

A review of the disturbance assessment methods used in various EIAs in UK and non-UK waters has been conducted. The detail of which assessment methodology was used in each development for each noise source is listed in **Data Appendix 1: Disturbance methods used in EIAs** and is summarised in Table 3.

Table 3 Summary of disturbance methods/thresholds used in EIAs in UK waters (UK) and non-UK waters (DK: Denmark, GER: Germany, NZ: New Zealand, USA) for various sound sources. Full details by development in Data Appendix 1: Disturbance methods used in EIAs.

Disturbance method/threshold	**Piling**	**Drilling**	**Dredging**	**Vessels**	**Geophysical survey**	**UXO**	**Wave & Tidal**
Fixed effective deterrence range	UK 15, 26 km GER ≤ 8 km	UK 3 m			UK 2.6, 5, 10, 12 km	UK 26 km	
Fixed SPL 140 dB re 1 μPa Low level disturbance (HESS 1997)					UK		UK
Fixed SPL 160 dB re 1μPa Level B harassment impulsive (NMFS 2005)	UK USA				UK USA	UK USA	
Fixed SPL 120 dB re 1μPa Level B harassment non-impulsive (NMFS 2005)		UK USA	UK USA	UK USA			UK USA
Fixed SPL 140 dB re 1μPa Low level disturbance impulsive (NMFS 2005)	UK					UK	
Fixed SEL_{ss} 140 dB re $1\mu Pa^2s$ (e.g. Dähne et al. 2013)	DK GER, NL						
Fixed 75 dB_{ht} (Species) mild avoidance (Nedwell et al. 2007)	UK	UK	UK	UK			UK
Fixed 90 dB_{ht} (Species) strong avoidance (Nedwell et al. 2007)	UK	UK	UK	UK			UK
Fixed TTS-onset SEL_{ss} and $L_{p,pk}$ (Southall et al. 2007)	UK	UK	UK		NZ 171dB SEL	UK	

Disturbance method/threshold	Piling	Drilling	Dredging	Vessels	Geophysical survey	UXO	Wave & Tidal
Fixed proposed behaviour response thresholds (derived from Southall et al. 2007) (Table 7)	UK				UK		UK
Fixed likely avoidance (derived from Southall et al. 2007) (Table 8)	UK						
Fixed possible avoidance (derived from Southall et al. 2007) (Table 8)	UK						
Fixed SEL 145 dB re 1 μPa^{2}s / $L_{p,pk}$ 174 dB re 1 μPa (Lucke et al. 2009)	UK	UK	UK	UK			UK
Fixed behavioural avoidance (Finneran and Jenkins 2012)		UK	UK	UK			
Fixed <80 vessels per day (Heinänen and Skov 2015)				UK			
Fixed unweighted median SPL RL 142 dB (derived from Hastie et al 2018)							UK
Fixed TTS-onset SEL_{cum} and $L_{p,pk}$ (NMFS, 2016, 2018) (Southall et al 2019)	UK		UK				
Dose-response curves	UK Porpoise, seals			USA Killer whale	UK Porpoise, minke whale USA Killer, pilot, sperm, humpback, beaked whales		

EIA context dependency

Understanding the pattern and severity of behavioural responses to noise is complicated due to the range of factors and potential circumstances that apply to each animal. As external and internal variables may interact and contribute to a given response, it is difficult to demonstrate, with certainty, the threshold that will trigger disturbance for marine mammals. In addition, quantifying a behavioural response should consider the relative importance for individual vital rates. For example, a strong startle response may be considered as severe. However, as a short-term change in state, may be recoverable and therefore may not negatively affect the animal in the future (i.e. such that the vital rates of the individual would be altered). In contrast, a cessation in feeding or communication over a longer period may have consequences for individual fitness (via reduced and uncompensated energy intake).

The response of an individual may relate to its history of noise exposure, and the subsequent consequences that it experienced (see the review of behavioural response studies in Harris et al. 2018 for further detail). Habituation and/or sensitization occurs over time and may develop through a combination of an animal's ingrained disposition, and associated learning. However, this response is also expected to be influenced by the motivation, sex, age and life stage of an animal, for example a mother with a young calf may respond differently when compared with a lone female. In addition to differences in individual behaviour and experience, the physiological condition of an animal is expected to influence its response. A healthy individual with a good body condition may be more easily deterred from high quality habitat than an animal in poor condition that has a strong need to maximize its foraging efficiency.

The context dependency of a behavioural response to noise make it difficult to quantify disturbance thresholds for marine mammals. In the context of responses to noise from offshore wind farm construction, such variability has been further demonstrated by the range of individual responses to noise in field studies. Pile driving at Luchterduinen and Gemini wind farms was associated with changes in behavioural state of some grey seals up to 36 km from the construction site. Conversely, other animals found only 12 km from the noise source showed little perceivable response (Aarts et al. 2018). It has been suggested that behavioural response to disturbance is considered in relation to context, where possible (Southall et al. 2007). Our understanding of behavioural response is currently limited by the quantity of empirical evidence available. Impact assessments should apply context-specific information to demonstrate the maximum potential threshold of behavioural response, but without further empirical knowledge of context, we are limited in our ability to make these predictions.

It is therefore important to understand that an impact assessment is only able to predict the potential for behavioural responses and has a limited ability to take context specific factors into account.

EIA density estimates

In order to quantitatively predict the number of animals disturbed by an underwater sound source, a baseline characterisation must be conducted in order to provide an estimate of the abundance and density of animals in the area of interest. There are two types of density estimates: uniform density estimates and density surfaces. A uniform density estimate assumes that there is a uniform density across a specific area (i.e. all animals within the area are uniformly distributed); for example, the design-based density estimates obtained from the SCANS III surveys, where a single density estimate is provided for each survey block. A density surface allows the density of animals to change continuously across an area at the spatial resolution of the density surface (i.e. the grid cell size), and so can take into consideration animals congregating in hot-spots and density changes with environmental variables (such as depth, sea surface temperature, sediment type etc). Examples of each type are shown in Figure 7, using the SCANS III block-wide density estimates for harbour porpoise (Hammond et al. 2017) and the grey seal habitat preference maps (Carter et al. 2020). It is expected that the number of animals predicted to experience disturbance will vary between the two methods. Under the uniform density estimate, the number of animals that may be impacted will be the same regardless of where the impact area lies within the survey block. With a density surface, the number of animals predicted to be disturbed will vary depending on the location of the impact area relative to areas of higher and lower density.

Another consideration for the density estimate for marine mammals is the size of the area the density estimate is representative of. For example, many developments will use the results of the site-specific baseline surveys as the density estimate that is taken forward to the quantitative impact assessment, as it will likely provide the most up-to-date and fine-scale (temporally and spatially) density estimates. However, the area surveyed during the site-specific surveys is never large enough to cover the entire impact area for marine mammals. Most often, site-specific surveys such as digital aerial surveys, are limited to the array area plus a small buffer (e.g. Dounreay Tri was array area +2 km buffer, Norfolk Vangaurd was array area +4 km buffer and Awel-y-Mor is array area +4-8 km buffer); however, disturbance impacts can extend well beyond this area (e.g. a disturbance dose-response curve for pile driving can extend to >50 km from the source). In this circumstance, the density estimate for the survey area is not necessarily representative of the density of animals outside of the survey area, especially at distances very far from the site. Sometimes this is considered within impact assessments, other times it is not. For example, the Hornsea Project Four quantitative impact assessment used a combination of the site-specific density estimates and the SCANS III density estimates, where the part of the impact area within the survey area was considered to contain the site-specific density, while the part of the impact area beyond the survey area was considered to contain the SCANS III density estimate instead. Where different sources of density are to be used in combination in impact assessments, it is important that the different assumptions and potential biases in the density data are identified and accounted for (e.g. accounting for surface availability and relative vs absolute density).

The density estimate (uniform or density surface) is the scalar used to estimate the number of animals within the impact area. The more realistic the density estimate/surface, the more realistic the predictions of impact.

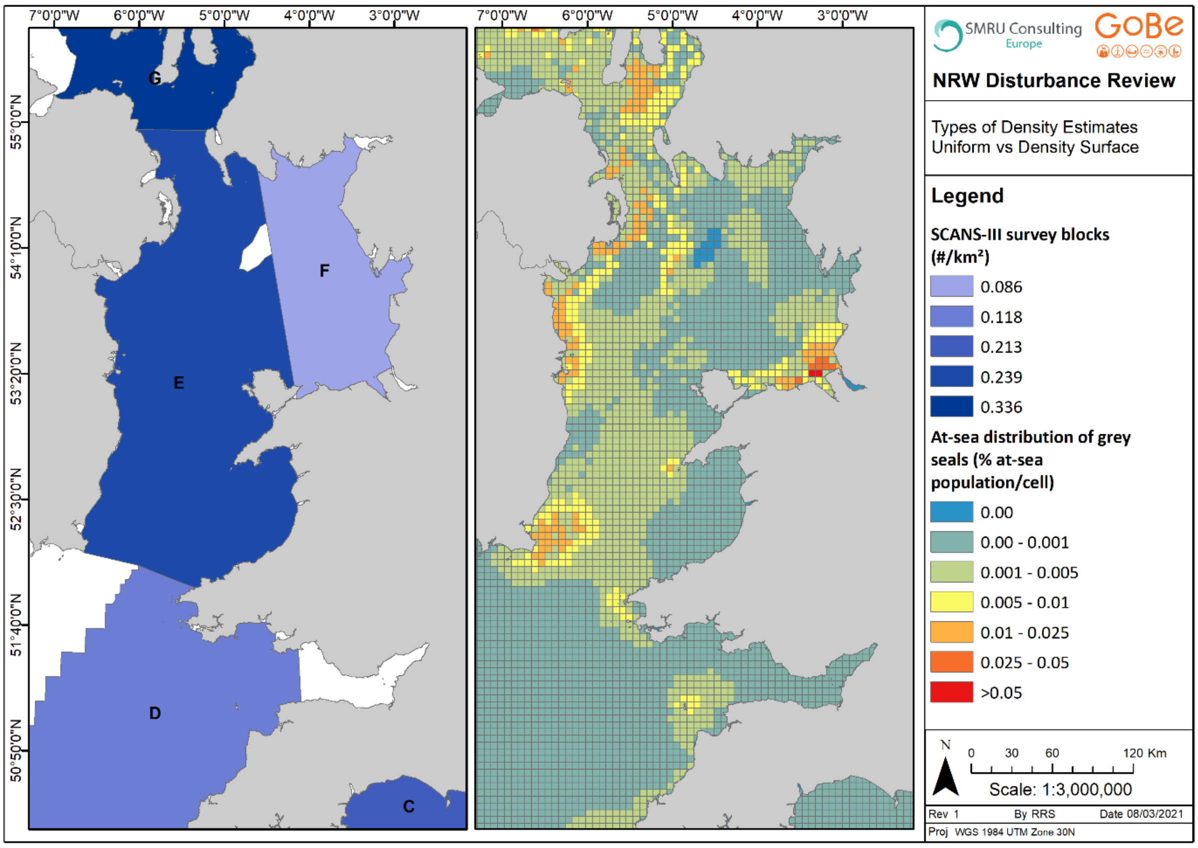

Figure 7 Examples of different types of marine mammal density surfaces available (data obtained from Hammond et al. 2017 for harbour porpoise and Carter et al. 2020 for grey seal).

EIA magnitude and sensitivity

The process for determining the significance of an impact is typically a three-stage process that involves: 1) defining the sensitivity of the receptor to the specific impact; 2) predicting the magnitude of the impact; and, 3) using a significance matrix to determine whether or not the magnitude/sensitivity combination is considered to result in a significant level of impact. As with the quantitative assessment of disturbance, there are no formal guidelines on what should be used for the definitions of magnitude and sensitivity, nor the significance levels obtained through different combinations in the matrix; therefore, recent offshore windfarm EIAs have used a combination of quantitative and qualitative definitions.

The below section provides the magnitude and sensitivity definitions used in the Norfolk Vanguard marine mammal ES chapter and the Hornsea Project Three marine mammal ES chapter. The definitions of sensitivity are similar, in terms of the ability of the individual receptor to avoid, tolerate or recover from the effect, although the Hornsea Three definitions extend this definition by including the likelihood of effect on reproduction and survival rates. The definitions of magnitude vary considerably between the two ES chapters, as Norfolk Vanguard uses a set of quantitative definitions (e.g. effect on 1% of population) while Hornsea Project Three uses qualitative definitions (e.g. effect likely to affect FCS or population trajectory). There are advantages and disadvantages to each approach. Often it is not known what level of impact would likely result in a change in the population size or trajectory, and therefore it can be counterproductive to assign quantitative values to the definitions. On the other hand, a quantitative impact assessment results in a prediction of the number of animals and percentage of the population predicted to be impacted, but it is up to the assessor to decide which qualitative definition that quantitative prediction aligns with, the justification for which is often lacking in many impact assessments.

In addition to the differences in the definitions of the magnitude/sensitivity, there are differences between impact assessments as to the number of categories used for magnitude/sensitivity in the significance matrix. Some impact assessments use: high, medium, low, negligible (4 categories), while others may use: very high, high, medium, low, negligible (5 categories). Again, there is no guidance to the number of categories used in significance matrices and as such these differ between impact assessments.

When reviewing the definitions of sensitivity and magnitude it is recommended that the regulator considers the species and population in question and whether or not there is sufficient evidence to justify the use of quantitative values in the definitions.

The following are examples of definition of sensitivity and magnitude used in recent offshore windfarm EIAs:

Sensitivity: Norfolk Vanguard ES 2018

- High: Individual receptor has very limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
- Medium: Individual receptor has limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
- Low: Individual receptor has some tolerance to avoid, adapt to, accommodate or recover from the anticipated impact.
- Negligible: Individual receptor is generally tolerant to and can accommodate or recover from the anticipated impact.

Sensitivity: Hornsea Project Three ES 2018

- **Very high**: No ability to adapt behaviour so that survival and reproduction rates are affected. No tolerance – Effect will cause a change in both reproduction and survival rates. No ability for the animal to recover from the effect.
- **High**: Limited ability to adapt behaviour so that survival and reproduction rates may be affected. Limited tolerance – Effect may cause a change in both reproduction and survival of individuals. Limited ability for the animal to recover from the effect.
- **Medium**: Ability to adapt behaviour so that reproduction rates may be affected but survival rates not likely to be affected. Some tolerance – Effect unlikely to cause a change in both reproduction and survival rates. Ability for the animal to recover from the effect.
- **Low**: Receptor is able to adapt behaviour so that survival and reproduction rates are not affected. Receptor is able to tolerate the effect without any impact on reproduction and survival rates. Receptor is able to return to previous behavioural states/activities once the impact has ceased.
- **Negligible**: Very little or no effect on the behaviour of the Receptor.

Magnitude : Norfolk Vanguard ES 2018

- High: Permanent irreversible change to >1% of the reference population OR Long-term effect (10 years+) to >5% of the reference population OR Temporary effect to >10% of the reference population.
- Medium: Permanent irreversible change to >0.01≤1% of the reference population OR Long-term effect (10 years+) to >1≤5% of the reference population OR Temporary effect to >5≤10% of the reference population.
- Low: Permanent irreversible change, >0.001≤0.01% of the reference population OR Long-term effect (10 years+) to >0.01≤1% of the reference population OR Intermittent and temporary effect to >1≤5% of the reference population.
- Negligible: Permanent irreversible change to ≤0.001% of the reference population OR Long-term effect (10 years+) to ≤0.01% of the reference population OR Intermittent and temporary effect to ≤1% of the reference population.

Magnitude: Hornsea Project Three ES 2018

- High: Impact would affect the behaviour and distribution of sufficient numbers of individuals, with sufficient severity, to affect the favourable conservation status and/or the long-term viability of the population at a generational scale.
- Medium: Temporary changes in behaviour and/or distribution of individuals at a scale that would result in potential reductions to lifetime reproductive success to some individuals although not enough to affect the population trajectory over a generational scale. Permanent effects on individuals that may influence individual survival but not at a level that would alter population trajectory over a generational scale.
- Low: Short-term and/or intermittent and temporary behavioural effects in a small proportion of the population. Reproductive rates of individuals may be impacted in the short term (over a limited number of breeding cycles). Survival and reproductive rates very unlikely to be impacted to the extent that the population trajectory would be altered .
- Negligible: Very short term, recoverable effect on the behaviour and/or distribution in a very small proportion of the population. No potential for any changes in the individual reproductive success or survival therefore no changes to the population size or trajectory.
- No change: No predicted effect.

EIA population consequences

The prediction of the population-level consequences of disturbance on marine mammals is a crucial part of the impact assessment and decision-making process. Therefore, the final step in a quantitative impact assessment for disturbance is an assessment of whether or not the levels of disturbance predicted for the sound source are likely to cause a change in the long-term population size or trajectory. Not all EIAs conduct this population modelling; it is typically not considered necessary to conduct population modelling unless the project-specific impacts are predicted to result in a significant level of impact. There are different population models that can be used to assess the population-level effects of disturbance, including predictive modelling/population viability analysis using matrix models (e.g.

iPCoD) or using individual-/agent-based models (e.g. DEPONS, AgentSeal). A review of, and guide to, the population models currently used in marine mammal impact assessment is provided in Sparling et al. (2017b).

All of these models require specific input data and have certain limitations and sensitivities. For example, iPCoD requires detailed demographic information and an understanding of the relationship between days of disturbance and individual survival and reproductive rates – information which is lacking or uncertain for some key marine mammal populations in the UK. Also, DEPONS (currently only suitable for harbour porpoise in the North Sea) requires population movement patterns, food availability maps and an understanding of the relationship between food intake, energy status and survival – again, which is lacking or uncertain for some marine mammal populations in the UK. Therefore, there are advantages and disadvantages to the application of each method to the assessment of disturbance (see below – note this does not include Potential Biological Removal as this method is considered to be unsuitable for the assessment of disturbance). There are no rules or guidance as to which model should be used for impact assessments (project alone, cumulative or different sound sources) and nor is there guidance on when a population model should be used in an impact assessment. Therefore, there is currently no consistency to the way in which population models are used in impact assessments, if at all.

For population modelling, an estimate of the number of animals that are predicted to be disturbed is required, and it is the proportion of the population disturbed and the level of repeated disturbance received by an individual that drives the changes for the population.

Therefore, it is important to obtain a realistic estimation of the number of animals predicted to be disturbed in order to estimate realistic population-level changes. As such, both the density estimate and threshold/method used in the disturbance assessment are important.

The following is summary information on population models, adapted from Sparling et al. (2017b):

IPCoD

Data requirements:

- Defined MU
- Demographic info
- # impacted daily
- Piling schedule
- Relationship between disturbance and survival/reproduction

Useful for:

- Cumulative impact assessment
- Prediction of population consequences for pile driving for UK priority species

Less useful for:

- Species/pressures with very limited data or no knowledge of relationship between number of days of disturbance and survival/reproductive rates

DEPONS

Data requirements:

- Defined Management Unit
- Demographic info
- Food availability map
- Response to noise
- Movement patterns
- Bioenergetics

Useful for:

- Cumulative impact assessments
- Effect of different spatial and temporal scenarios of impact
- Effects of different behavioural thresholds

Less useful for:

- Does not exist for mammal species/ populations other than harbour porpoise

EIA examples

Thanet Extension Offshore Wind Farm

The Thanet Extension EIA (Vattenfall Wind Power Ltd 2018) is the only EIA to our knowledge to present site-specific underwater noise modelling for both the Lucke et al. (2009) 145 dB SEL_{ss} threshold (Figure 8) as well as the porpoise dose-response approach (Figure 9) for a real-world comparison. The Thanet Extension assessment used the SCANS III porpoise density estimate of 0.607 porpoise/km^2 for both disturbance assessment approaches. Given that a uniform density surface was used, it is simple to calculate the number of porpoise predicted to be impacted using a 26 km EDR for a further comparison of the EIA results with those obtained when using the EDR. The number of porpoises predicted to be disturbed was broadly similar between the three methods, ranging between a maximum of 1,880 porpoise under the dose-response method to a minimum of 1,289 porpoise under the 26 km EDR method (Table 4).

Table 4 Number of harbour porpoise predicted to experience behavioural disturbance under three assessments methods – taken from the Thanet Extension EIA (Vattenfall Wind Power Ltd 2018)

Threshold	Number of porpoise disturbed
Fixed 26 km EDR	1,289
Lucke et al. (2009) fixed 145 dB SEL_{ss}	1,621
Harbour porpoise dose-response curve	1,880

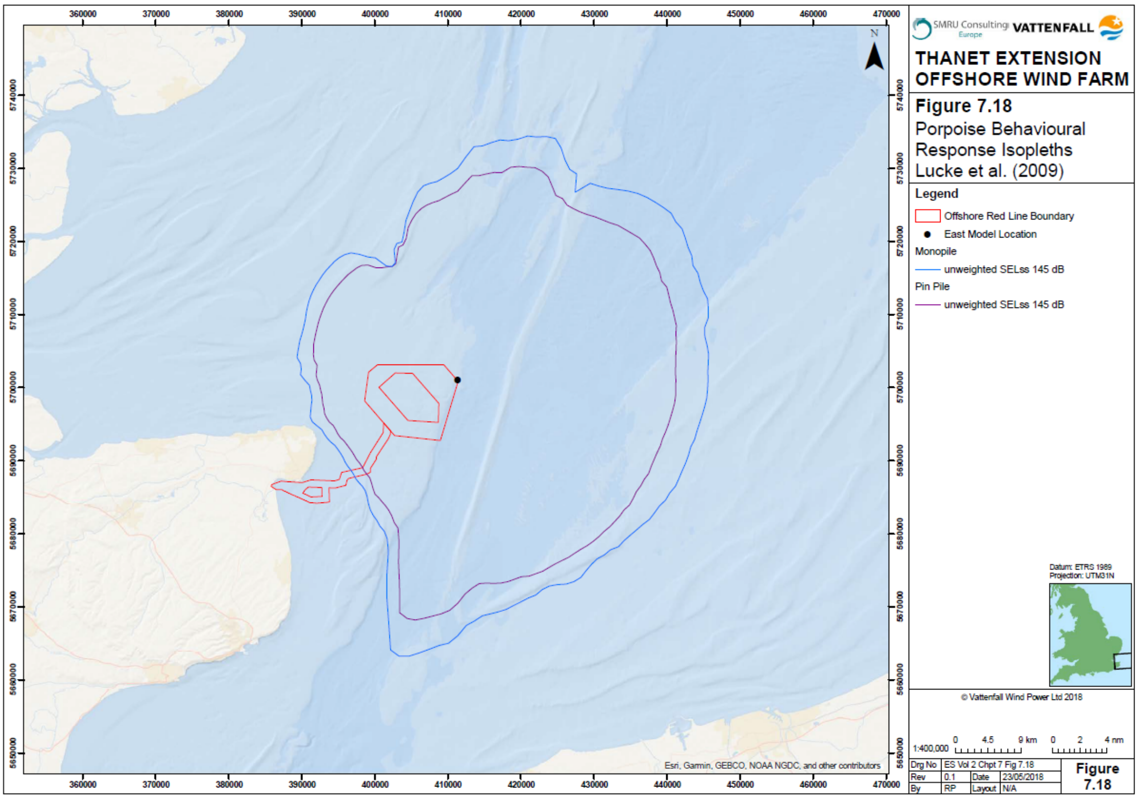

Figure 8 Thanet Extension porpoise behavioural response isopleths using the Lucke et al. (2009) fixed threshold (Vattenfall Wind Power Ltd 2018)

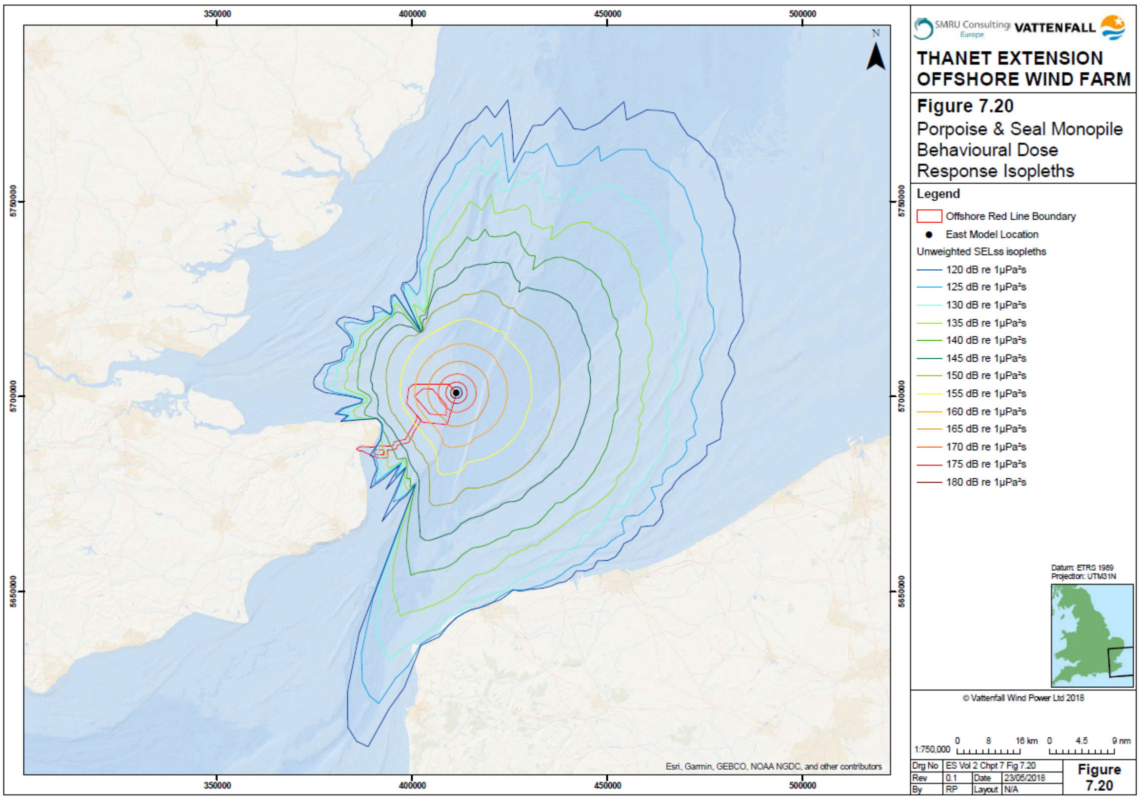

Figure 9 Thanet Extension porpoise behavioural response isopleths using the dose-response approach (Vattenfall Wind Power Ltd 2018)

Theoretical worked example

In order to demonstrate the range of results that can be predicted under the different assessment methods and using different density surfaces, we have provided a theoretical worked example. The worked example assumes a monopile is driven into the seabed in Welsh waters, and presents illustrative predictions of impact assuming an effective deterrence range (26 km), a fixed noise threshold (145 dB SEL_{ss}) and a dose-response, assessed using both a uniform density estimate and two examples of a spatially explicit density estimate (Figure 11, Figure 12). When applying an EDR based approach, it is important to note that the method was developed as a habitat based approach and not an individual based approach; as noted earlier it is intended to represent an average habitat loss for all individuals as a result of disturbance (typically within a defined area) and not specifically to enable the number of animals that may be disturbed to be calculated (though some EIAs have used it as such).

While actual site-specific underwater noise propagation modelling was outside the scope of this work, indicative impact ranges have been created, based on mean impact ranges from impact assessments from other offshore windfarms. While this approach is limited and doesn't represent "real-world" impact ranges and underwater noise propagation effects, it provides an illustrative example as a way of comparing the different assessment methods with different assumptions about species density.

The uniform density estimate used was the SCANS III block E (Celtic/Irish Seas) estimate of 0.239 porpoise/km^2 (Hammond et al. 2017) (Figure 10). The spatially explicit density surface used was a hypothetical density surface assuming a) the density of harbour porpoise decreased with distance from the coast (Figure 11) and b) the density of harbour porpoise increased with distance from the coast (Figure 12) between 0.0 and 0.35 porpoise/km^2.

The worked example demonstrates that the effective deterrence range of 26 km results in significantly fewer porpoise predicted to be disturbed compared to the fixed noise threshold and the dose-response curve, under all of the three density assumptions (Table 5). The modelling subsequently demonstrates that the predicted number of porpoise impacted from both the fixed noise threshold and the dose-response approaches are similar for the uniform density and for the model with high numbers of coastal porpoise. Conversely, the number of porpoises predicted to be impacted is higher for the dose-response approach compared to the fixed threshold for an assumed porpoise density increasing with distance away from the coast (Table 5). This is because the potential disturbance range and therefore the overall area impacted differs significantly (Figure 11, Figure 12). In this worked example the disturbance range using the fixed noise threshold extends out to 37.8 km from the piling source, while for the dose-response approach, the 120 dB re 1 $\mu Pa^2 s$ SEL_{ss} contour extends out to 75.3 km from the piling source, and therefore include porpoises at longer distances from the coast. For the "real-world" Thanet Extension example, the fixed noise threshold extends to a maximum of ~38 km from the piling source, while the dose-response 120 dB re 1 $\mu Pa^2 s$ SEL_{ss} contour extends to a maximum of ~93 km from the piling source (Figure 8 and Figure 9).

This example shows that it is not only the disturbance assessment method that influences the resulting predictions, but so does the underlying density surface used in the assessment. It also shows that the choice of disturbance assessment has implications on any calculation of disturbance area for purposes of harbour porpoise SAC assessment.

The resulting predictions of the number of animals disturbed in this worked example vary considerably with the density surface used, even though the impact contour and density contour areas remain the same (Table 5). While the density surfaces used in this worked example are hypothetical, they do illustrate that the choice of density surface used in the quantitative impact assessment can have large implications on the resulting predictions.

Table 5 Number of harbour porpoise predicted to be disturbed under the worked example, using three different disturbance assessment methods and a uniform density surface, a density surface with high densities at the coast and a density surface with low densities at the coast.

Number of harbour porpoise disturbed

Threshold	Uniform density (Figure 10)	Density surface high at coast (Figure 11)	Density surface low at coast (Figure 12)
Fixed 26 km EDR	503	552	275
Lucke et al. (2009) fixed 145 dB SELss	963	1,064	512
Harbour porpoise dose-response curve	927	1,006	720

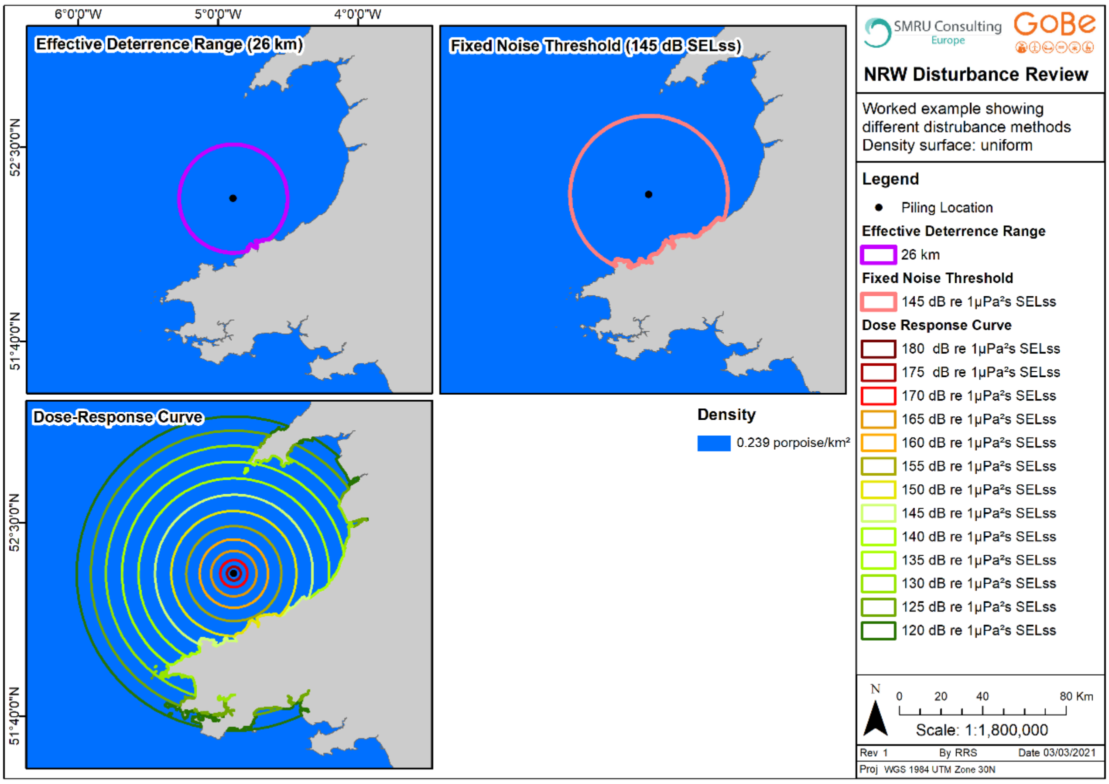

Figure 10 Worked example showing different disturbance methods for a hypothetical pile driving event using a uniform density.

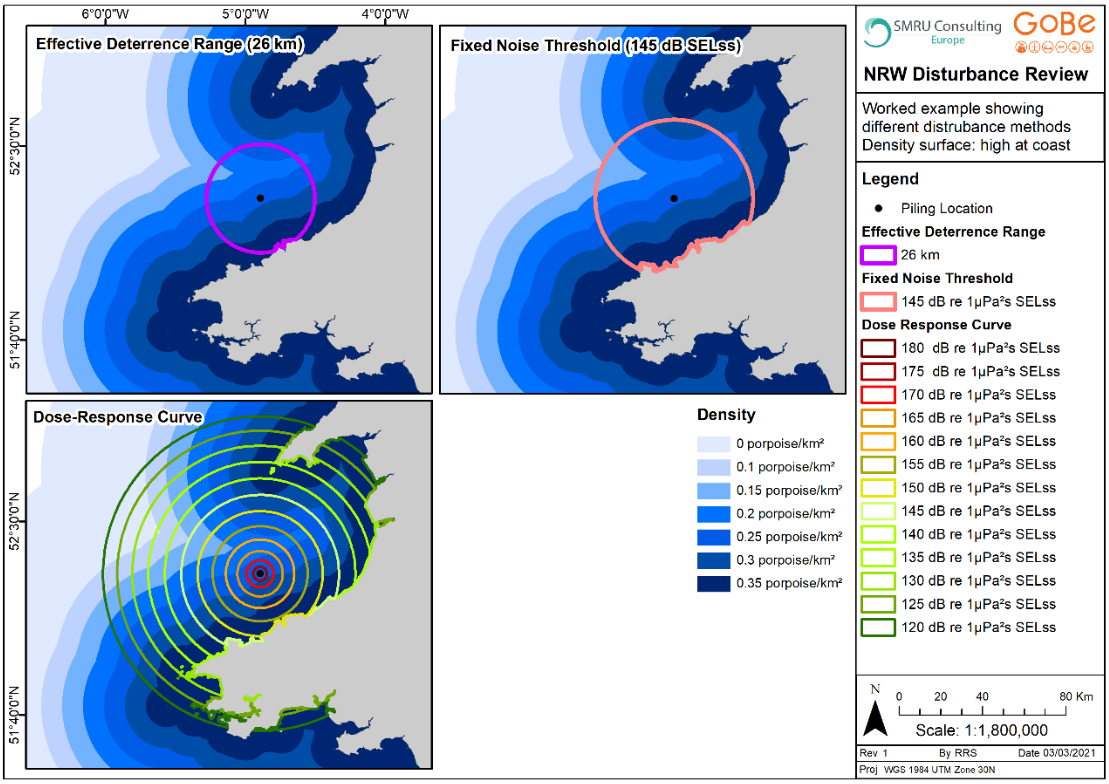

Figure 11 Worked example showing different disturbance methods for a hypothetical pile driving event using a density surface with higher densities at the coast.

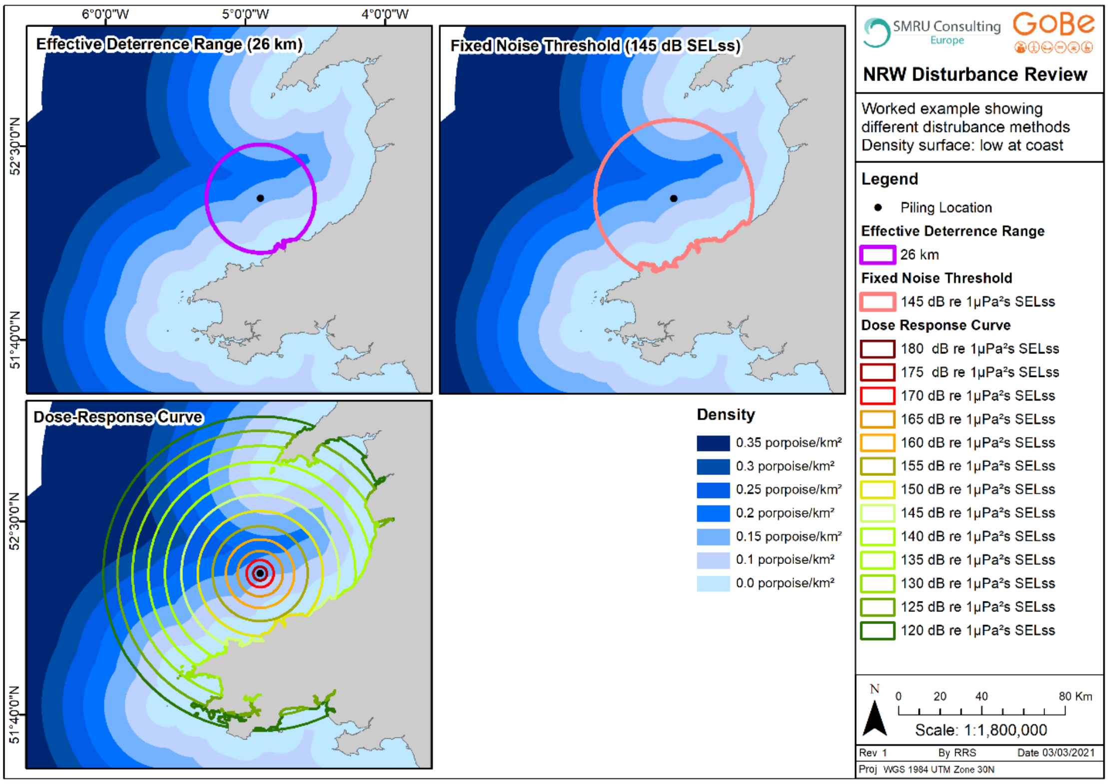

Figure 12 Worked example showing different disturbance methods for a hypothetical pile driving event using a density surface with lower densities at the coast.

Review of methods used for HRA

Marine Mammal SACs in Welsh Waters

The **Habitat Regulation Assessment** (HRA) process (defined in **Appendix 3: Overview of the HRA Process and SACs in Welsh Waters: HRA Process**) requires consideration of certain designated sites, which for marine mammals are Special Areas of Conservation (SACs). There are three marine mammal species which are designated features of SACs in Wales:

- Grey seal (Cardigan Bay/ Bae Ceredigion SAC, Pembrokeshire Marine/ Sir Benfro Forol SAC and Pen Llŷn a'r Sarnau/ Lleyn Peninsula and the Sarnau SAC);
- Harbour porpoise (Bristol Channel Approaches / Dynesfeydd Môr Hafren SAC, North Anglesey Marine / Gogledd Môn Forol SAC and West Wales Marine / Gorllewin Cymru Forol SAC); and
- Bottlenose dolphin (Cardigan Bay/ Bae Ceredigion SAC and Pen Llŷn a'r Sarnau/ Lleyn Peninsula and the Sarnau SAC).

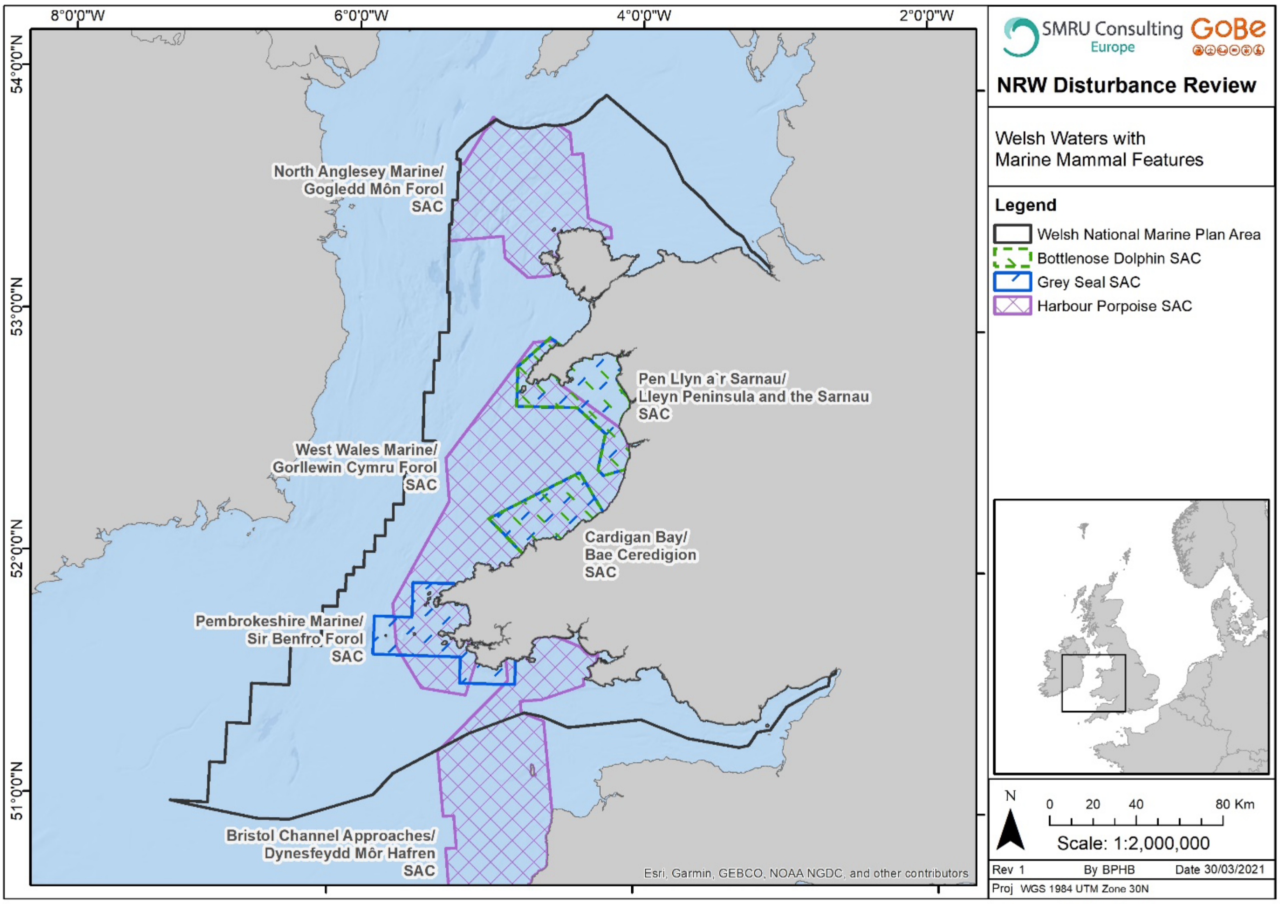

Figure 13: Marine Mammal SACs in Welsh Waters

Further information on each site within Welsh waters is detailed below, provided in **Appendix 3: Overview of the HRA Process and SACs in Welsh Waters: Marine Mammal SACs in Welsh Waters**. The management units for the species designated in sites within Welsh waters are shown in Figure 14. There are a number of other SACs for these species within the management units but not in Welsh waters. Those sites are detailed in as follows:

- Grey seal (**UK**: North Rona SAC; Isles of Scilly Complex SAC; Lundy SAC; Monach Islands SAC; Treshnish Islands SAC; The Maidens SAC. **Ireland**: Roaringwater Bay and Islands SAC; Horn Head and Rinclevan SAC; Slieve Tooey/Tormore Island/Loughros Beg Bay SAC; Inishbofin And Inishshark SAC; Slyne Head Islands SAC; Duvillaun Islands SAC; Saltee Islands SAC; Lambay Island SAC; Inishkea Islands SAC; Blasket Islands SAC. **France**: Ouessant-Molène SCI; Chaussée de Sein SCI);
- Harbour porpoise (**Ireland**: Blasket Islands SAC; Roaringwater Bay And Islands SAC; Rockabill to Dalkey Island SAC. **Northern Ireland**: North Channel SAC. **France**: Nord Bretagne DH SCI; Côte de Granit rose-Sept-Iles SCI; Tregor Goëlo SCI; Baie de Morlaix SCI; Abers - Côte des legends SCI; Ouessant-Molène SCI; Chaussée de Sein SCI; Mers Celtiques - Talus du golfe de Gascogne SCI);
- Bottlenose dolphin (Lambay Island SAC, Saltee Islands SAC).

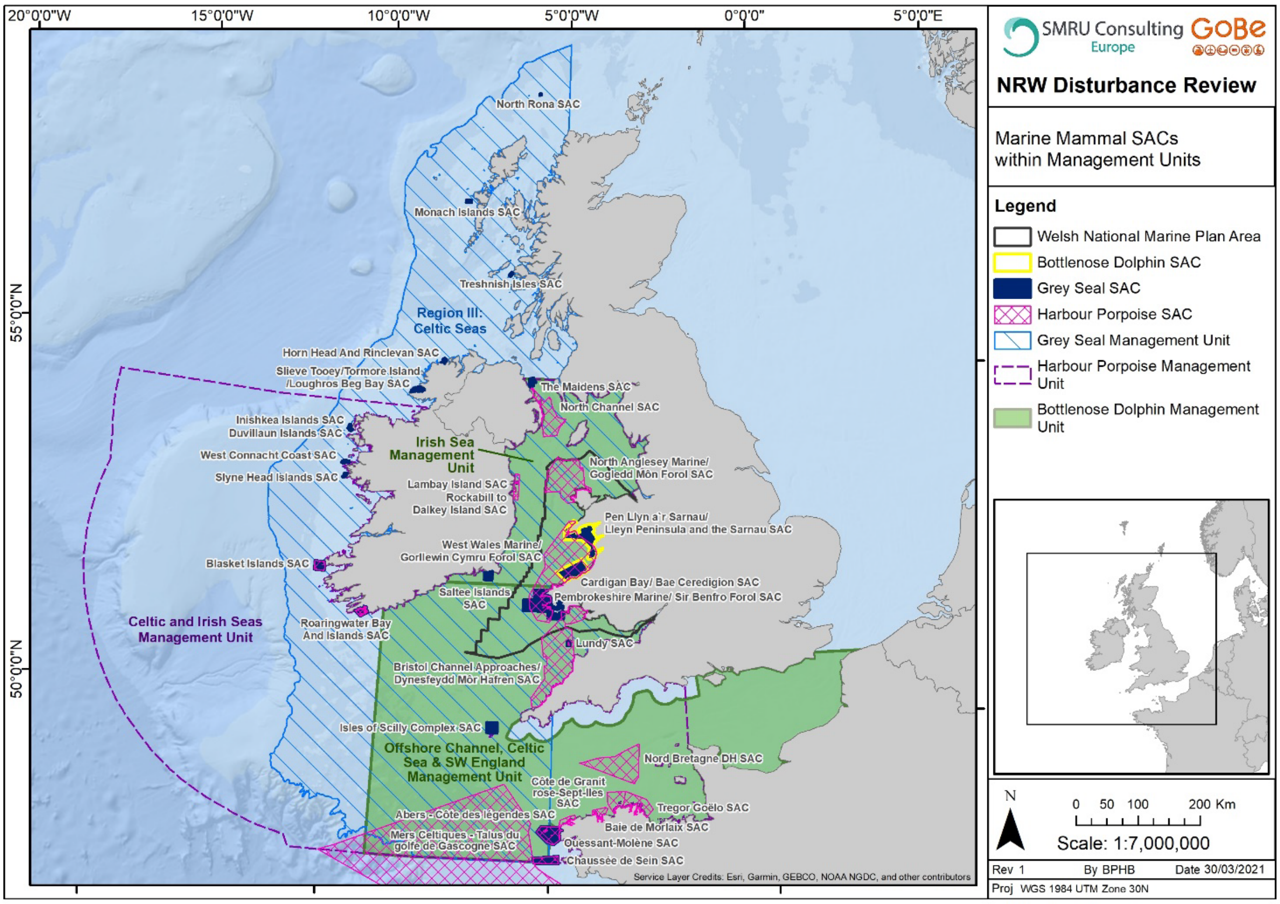

Figure 14: Marine Mammal SACs within Management Units which overlap with Welsh waters

Existing Guidance on Assessing Disturbance in SACs

A number of guidance documents have been identified, aimed at providing the context and approach taken to defining the significance of and/or assessing disturbance of marine mammals as a consequence of underwater noise, specifically in the context of HRA. Where documents are relevant to EPS (which in UK waters include all cetaceans), these have also been included as the driving legislation is the same as is the aim of achieving/maintaining Favourable Conservation Status. These documents are summarised in **Appendix 3: Overview of the HRA Process and SACs in Welsh Waters**.

Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs, JNCC et al 2020

- Country: England and Northern Ireland
- Species: Harbour porpoise

Definition of Significant Disturbance: Significant disturbance is interpreted as a reduction of the range of the species within the site or a reduction in the access to available habitat within the site. Management of noise in the sites should ensure that disturbance does not lead to the deterrence of harbour porpoise from a significant portion of the site for a prescribed period of time.

Threshold Applied: Driven by the conservation objective and is habitat based, with thresholds set at up to 20% per day or 10% across a season (with the guidance specifying the application of fixed range EDRs).

NRW position on: Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs. (England & Northern Ireland) (unpublished)

- Country: Wales
- Species: Harbour porpoise

Definition of Significant Disturbance: Significant disturbance applied through the JNCC (2020) 10%/20% thresholds

Threshold Applied: Threshold for significant disturbance defined, uncertain as regards how to assess a projects contribution to those thresholds

Conservation and Management Advice: Inner Hebrides and the Minches SAC (NatureScot 2020)

- Country: Scotland
- Species: Harbour porpoise

Definition of Significant Disturbance: Significant disturbance is interpreted to mean disturbance that affects the integrity of the site through alteration of the distribution of harbour porpoise within the SAC such that recovery cannot be expected or effects can be considered long term. Specific reference to effects lasting 8 years or more.

Threshold Applied: No threshold. To take account of factors for example those that may limit recovery, ability of individual animals to access alternative food sources etc

The protection of marine European Protected Species from injury and disturbance (JNCC et al, 2010)

- Country: England and Wales
- Species: All cetaceans

Definition of Significant Disturbance: Significant disturbance would increase the risk of a negative impact to a population of an EPS at Favourable Conservation Status (FCS).

Threshold Applied: Southall et al (2007) behaviour scoring is referenced, together with displacement of animals with subsequent unnatural distribution

The protection of Marine European Protected Species from injury and disturbance (Marine Scotland, 2020)

- Country: Scotland
- Species: All cetaceans

Definition of Significant Disturbance: Acknowledged as not clear cut but dependant on a number of factors such as spatial/temporal distribution of animals, duration of activity, learnt behaviour, similarity to biological important sounds and motivation to remain.

Threshold Applied: Cetacean Risk Assessment taking account of specifics of the activity/sound, in-combination effects, Southall et al (2007) thresholds for injury (noting that disturbance is 'highly context specific and currently there are no agreed thresholds') and mitigation

JNCC/SNCB guidances

- JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (seismic survey guidelines), 2017
- JNCC guidelines for minimising the risk of disturbance and injury to marine mammals whilst using explosives, 2010
- Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise 2010

- Country: UK waters
- Species: Marine mammals

Definition of Significant Disturbance: Not defined

Threshold Applied: Identifies mitigation measures for injury, noting that the measures may also reduce risk of disturbance

Regulation 37 Advice

- Country: Marine sites (Welsh example reviewed)
- Species: Grey seal and bottlenose dolphin

Definition of Significant Disturbance: Disturbance by human activity is below levels that suppress reproductive success, physiological health or long-term behaviour

Threshold Applied: Not identified

Concept for the Protection of Harbour Porpoises from Sound Exposures during the Construction of Offshore Wind Farms in the German North Sea (ASCOBANs, 2014)

- Country: Germany
- Species: Harbour porpoise

Definition of Significant Disturbance: A significant disturbance would be considered one where the conservation status of the local population worsened

Threshold Applied: Fixed noise threshold at defined range from source (750 m), with resultant EDR out to 8 km, combined with area/habitat based threshold (10% typically, reducing to 1% for some areas/some months)

Marine mammals and underwater noise in relation to pile driving – Working Group 2014 (Anon, 2015)

- Country: Denmark
- Species: Harbour porpoise, some reference to seals

Definition of Significant Disturbance: Population based criteria to determine significance (population decline)

Threshold Applied: Fixed noise thresholds (presumably at source) is recommended but it is not clear what the aim is (183 dB cumulated SEL (unweighted) for harbour porpoise and 200 dB cumulated SEL (unweighted) for seals)

Underwater noise and marine mammals (Energinet.dk, 2015)

- Country: Denmark
- Species: Harbour porpoise and seals

Definition of Significant Disturbance: Not defined

Threshold Applied: Fixed noise threshold for PTS. TTS and disturbance assessment, combined with species density and flee response, with modelled cumulative sound exposure and number of animals affected

Guideline for underwater noise – Installation of impact-driven piles (Center for Energiressourcer, 2016)

- Country: Denmark
- Species: Marine mammals

Definition of Significant Disturbance: Not defined

Threshold Applied: Fixed threshold for cumulative SEL (assumed to be for injury)

Updated Conservation Plan for the Harbour Porpoise Phocoena phocoena in the Netherlands: Maintaining a Favourable Conservation Status

- Country: Netherlands
- Species: Harbour porpoise

Definition of Significant Disturbance: Not defined

Threshold Applied: Fixed threshold for cumulative SEL (at 750 m)

Disturbance in HRA

A wide variety of plans and projects have potential to produce noise, with potential for disturbance from noise commonly addressed through the HRA process, with relevant noise sources addressed in HRA typically following those addressed in EIA.

Appendix 5: HRA disturbance examples provides examples that have been selected for information on the three species of interest and in relation to a variety of different types of plans or projects from different jurisdictions. The section below summarises the plans and projects reviewed, including the project name, the relevant site and species considered in the review (noting that other sites/features may have been included within the assessment), the noise disturbance concern and the method applied for assessment.

Summary of HRAs Reviewed

Thanet Extension Offshore Wind Farm

- **Designated site:** Southern North Sea SAC
- **Feature:** Harbour porpoise
- **Noise Disturbance:** Piling, UXO clearance, marine survey, vessel traffic and seabed preparation
- **Assessment approach:** The SNCB EDR approach (JNCC et al, 2020) combined with habitat based thresholds (20% per day/10% per season)

Review of Consented Offshore Wind Farms in the Southern North Sea

- **Designated site:** Southern North Sea SAC

- **Feature:** Harbour porpoise
- **Noise Disturbance:** Piling and survey, some consideration to bubble curtains and ADDs
- **Assessment approach:** Two approaches: SNCB EDR approach (JNCC et al, 2020) combined with habitat based thresholds (20% per day/10% per season), ASCOBANS derived population level threshold (ASCOBANS, 2014) (<1.7% of MU population) assessed through underwater noise modelling, fixed noise threshold, project specific species density and dose response curve

Projet de Parc Eolien en Mer de Saint-Nazaire:Evaluation des incidences Natura 2000

- **Designated site:** French waters
- **Feature:** Minke whale, bottlenose dolphin, harbour porpoise and grey seal
- **Noise Disturbance:** Piling
- **Assessment approach:** Underwater noise modelling using 145 dB SEL (assumed to be dB re 1μPa^{2}s) as the threshold at which animals will flee.

Swedish Court of Appeal Case 2014-M 6960

- **Designated site:** Swedish waters
- **Feature:** Harbour porpoise
- **Noise Disturbance:** Piling
- **Assessment approach:** Applied the German methodology (fixed noise threshold for auditory injury at 750 m, with resultant EDR for behaviour)

Dundee Local Development Plan 2

- **Designated site:** Isle of May SAC
- **Feature:** Grey seal
- **Noise Disturbance:** Piling, tourism and leisure activity, construction vessels
- **Assessment approach:** Requirement for management plans to be submitted to avoid significant disturbance

Wylfa Newydd Project

- **Designated site:** Several SACs, including 3 in Welsh waters
- **Feature:** Grey seal, bottlenose dolphin and harbour porpoise
- **Noise Disturbance:** Drilling, dredging, rock breaking/cutting, vessel movement
- **Assessment approach:** For grey seal and bottlenose dolphin, underwater noise modelling with fixed noise disturbance threshold (applying TTS as a proxy on advice of NRW, NRW pers. Comm.) combined with species density to calculate number of individuals that may be affected as a proportion of the

MU population. Similar approach for harbour porpoise, differing by being area of the SAC within the modelled thresholds as a % of the total SAC.

Nigg Bay Harbour Facility Habitat Regulations Assessment

- **Designated site:** Moray Firth SAC
- **Feature:** Bottlenose dolphin
- **Noise Disturbance:** Blasting, drilling, impact piling and dredging
- **Assessment approach:** Underwater noise modelling with fixed noise thresholds to predict range of effect (for onset of PTS, TTS and disturbance), with mitigation measures to minimise displacement from key feeding areas (amongst other measures) and acknowledgement of existing background noise

Natura Impact Statement for the Development of a 1:15 Scale Test Site for Wave Energy Devices at Belmullet Co. Mayo

- **Designated site:** West Connacht Coast SAC
- **Feature:** Bottlenose dolphin
- **Noise Disturbance:** Vessel noise and operational noise from device(s)
- **Assessment approach:** Risk assessment, Southall et al 2007 non-pulsed noise thresholds (values tabulated in the report for PTS and behavioural response), nature/type of noise to be generated, use of area by cetaceans, background noise/existing activity

Applicability to SACs in Welsh Waters

To understand the various approaches taken within HRA to define significant disturbance from underwater noise and how to assess such disturbance, a number of documents have been reviewed from various different countries where the Habitats Directive applies. These have included both guidance documents and assessments, which address the question for different marine mammal species and for a variety of different types of plans or projects. A number of themes are, however, apparent, which are summarised as follows:

Defining Significant Disturbance

There are many ways to define significant disturbance (as highlighted earlier in the report). The following are often taken into account in HRA.

- **Population level** – in particular for methods involving counting individuals, it is the consequence to a population that is considered key, (although not typically quantified in assessments) with possible measures including disturbance sufficient to suppress reproductive success, physiological health or long term behaviour;
- **Habitat** – availability of sufficient undisturbed habitat to support the population;
- **Favourable Conservation Status** – where referenced, a significant disturbance is typically viewed as being sufficient to have a negative effect

on FCS, which can be related to species range, habitat availability and species density/distribution;
- **Temporal** – duration of effect is important when determining if disturbance is significant, with specific references (where made) linked to species life cycle and use of key areas; and
- **Habituation and motivation** – learnt behaviour, existing background noise and motivation to remain can all influence potential for disturbance to be significant.

With respect to significant disturbance being at individual or population level (or somewhere in between), the Supreme Court judgement in Morge vs Hampshire County Council (2011) as referenced by NRW during the drafting of the current document is noted. The case is also referenced in (DTA Ecology and Ecology 2020). Central to the case (among other matters) is when disturbance would be considered significant and the associated implications under the Habitats Directive. The case included discussion around how many individuals would need to be disturbed for population level disturbance to occur. The case highlighted the importance of the conservation status of a species, how rare the species is and whether a disturbance could affect the species/conservation status at population or biogeographic level. Overall, it indicates that consideration of what would constitute a disturbance or significant disturbance should be made on a species by species basis.

Assessment of Disturbance

- **Species based**– such approaches consider the number of individuals that may be disturbed as a percentage of a defined population (typically total population and not site based population). It may assume all individuals are affected/respond or may apply a dose-response curve;
- **Habitat based** – such approaches consider the availability of undisturbed habitat as a percentage of the total habitat within the site or within the population extent. The area disturbed may be defined by a fixed range (e.g. EDR) per activity or through modelling and can assume full disturbance/displacement or apply a dose-response curve;
- **Temporal** – a number of approaches consider the importance of a designated site (or area of sea) as that changes through the year, for example during breeding, with the weight given in the assessment varying temporally;
- **Fixed thresholds** – these can be applied to species based and habitat based assessments. They are based around either a fixed noise level above which an effect is deemed to occur (and typically rely on modelling to define how that applies at distance from source) or a fixed distance within which an effect is deemed to occur based on a specific activity (the EDR approach);
- **Behaviour scoring** – tends to be applied to older guidance/assessments and draws on Southall et al (2007); and
- **Risk based** – a number of approaches take account of site and project variables to determine potential consequences in a more subjective way, e.g. potential to limit recovery, alternative foraging sites etc.

The SACs within Welsh waters which host a designated marine mammal feature, together with relevant conservation objectives, are identified in the comparison below. While all conservation objectives are relevant, the most relevant to underwater noise disturbance is highlighted here.

The following is a comparison of potential approaches to HRA Disturbance Assessments and Welsh Conservation Objective Requirements:

Cardigan Bay/Bae Ceredigion SAC and Pembrokeshire Marine/ Sir Benfro Forol SAC

- **Marine Mammal Species:**
  - Grey seal (Both SACs).
  - Bottlenose dolphin (Cardigan Bay only).
- **Relevant Conservation Objective(s) in Welsh Waters:**
  - CO2: The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future.

  With specific reference made to:
  - Range within the SAC and inter-connected areas, appropriate and sufficient food within the SAC and beyond and supporting habitat.
- **Key considerations and possible options for assessment:**
  - The conservation objective is strongly linked to species range, which implies that a habitat based and not species based approach may be more relevant.
  - Disturbance sufficient to reduce range (loss of habitat) or act as a barrier to movement to supporting habitat wouldmore likely to be viewed as significant (depending on duration).
  - Should value of habitat vary temporally (e.g. for breeding) that should be taken into account when determining significance.

Pen Llŷn a`r Sarnau/ Lleyn Peninsula and the Sarnau SAC

- **Marine Mammal Species:**
  - Grey seal.
  - Bottlenose dolphin.
- **Relevant Conservation Objective(s) in Welsh Waters:**
  - CO2: The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future.
- **Key considerations and possible options for assessment:**
  - No preference to how a habitat based assessment should be conducted is apparent. Therefore the approach could apply a fixed range per activity (the EDR approach, although no such EDRs are available for grey seal or bottlenose dolphin) or apply a range based on modelling (based on fixed noise threshold values, noting limited data on these for grey seal). Both approaches could assume full disturbance/displacement within the resulting area or apply a dose-response curve if species density/distribution data are available.

The Bristol Channel Approaches/Dynesfeydd Môr Hafren SAC, West Wales Marine / Gorllewin Cymru Forol SAC, North Anglesey Marine/Gogledd Môn Forol SAC

- **Marine Mammal Species:**
    - Harbour porpoise.
- **Relevant Conservation Objective(s) in Welsh Waters:**
    - CO2: There is no significant disturbance of the species
- **Key considerations and possible options for assessment:**
    - Significant disturbance is defined through the spatial and temporal thresholds set out in JNCC et al (2020), as 20% daily and 10% seasonally. That strongly implies that a habitat based approach should be applied to the assessment.
    - How the habitat affected by significant disturbance should be quantified is not defined. Therefore the approach could apply a fixed range per activity (the EDR approach) or apply a range based on modelling (based on fixed noise threshold values). Both approaches could assume full disturbance/ displacement within the resulting area or apply a dose-response curve if species density/distribution data are available.

Recommendations

Disturbance from underwater noise is a major impact pathway for marine species, including those for which SACs have been designated. However, there is limited guidance on the methodology that should be applied when assessing behavioural disturbance to marine mammal species in the UK. The methodology used in EIAs and HRAs has also evolved over time as new scientific knowledge has been gathered. Guidance on assessing behavioral disturbance, therefore, needs to be developed for use in the UK/Wales. The following recommendations would ensure compatibility and consistency of environmental assessments through various guidance documents, including threshold specific recommendations, and would ensure that the most up-to-date and robust assessment tools are adopted.

Guidance documents

We recommend the development of three key guidance documents: a regulatory guidance document, a threshold guidance document and a population guidance document. The sections below detail what we recommend should be included within each guidance document.

Regulatory guidance

We recommend that NRW consider approaches used in other countries (see section 'EIA approaches of different countries') and **establish a regulatory guidance document** for Welsh waters that addresses the following:

- Development/expansion of HRA specific guidance (e.g. NRW 2020) on the assessment of disturbance for seals and bottlenose dolphins (and harbour porpoise in Welsh SACs), and general EIA guidance for marine mammals (which would involve many of the aspects below)
- Clear definitions of (significant) behavioural disturbance (see section Definition of significant disturbance)
- Definitions of magnitude, sensitivity and significant levels, considering whether there is sufficient evidence to justify the use of quantitative definitions
- Guidance on how applicants should outline the assumptions behind their assessment approach
- Guidance on thresholds, definitions and approaches to assessments
    - e.g., sound units need to be specified and defined, distance from sound source (SPL @ 1 m or 750 m)
    - Recommendation to follow specific ISO standards or appropriate guidance documents as listed in this inventory document.
- Guidance should be maintained as a "live document":
    - Developed through a working group to establish guidance and to keep it up to date (members should be a combination of relevant developers, SNCBs, consultancies and scientists), with yearly meetings and an appropriate review cycle (e.g. five-years)
    - Official interim amendments may be needed if major updates happen during a review cycle
    - Further development through expert workshops
    - Website with updates and communication tools to keep developers, consultancies and stakeholders up-to-date
- A framework should be followed/developed to address and reduce uncertainties
- A priority list of research is required to fill knowledge gaps. This could be based on a (ranked) gap-analysis.
    - e.g. development of a grey seal and a bottlenose dolphin dose-response curve and EDR for pile driving may be a priority research topic as these are both key protected species in Welsh waters and pile driving represents one of the main and loudest sound sources expected in future developments.
- Guidance needs to be adaptable, i.e. not too prescriptive but with the ability to tailor assessments to specific projects
    - e.g. methods must be species/ species group specific (based on their sensitivity, habitat use)
    - Where data are unavailable, the applicant must justify the transferability of the method used, use it with precaution and identify limitations (e.g. the use of porpoise D/R for minke whale, harbour seal D/R for grey seal)

- Guidance should include a plan for a strategic monitoring of Welsh waters to minimise the danger of different assumptions and potential biases in the density data.

Threshold guidance

We recommend an appropriate **threshold guidance document** with explanations on thresholds and their usage.

- An overall aim should be to ensure that any recommended threshold is derived from a range of representative sites and sources in order to be taken forward as a generalised threshold to other sites for impact assessment
- Proposed thresholds should be underpinned with research as much as possible to enable robustness
- Limitations should be made obvious (e.g. threshold obtained from one specific study/species/location/sound source for use in future assessments)
- Guidance should be maintained as a live document, acknowledging increasing information over time
- Investigate appropriate behavioural thresholds for moving point sources (e.g. seismic surveys, construction vessels), which are currently lacking.

Population guidance

We recommend a **population guidance document** for Welsh waters.

- Guidance should be maintained as a live document to be updated when new or updated information becomes available
- Include current population/ management unit estimates and assessments (including seals at sea) and their natural variation to be used as reference population
- Limitations of the abundance and density estimates should be made obvious
- Include a data gap analysis on missing information
- Explore and decide on which populations and management units should be used in Welsh waters/ specific areas of Welsh waters as the appropriate reference population
- Explore and decide on a species/ species group/ conservation status specific threshold for the percentage of the population predicted to be disturbed that would trigger a requirement for population level modelling
- Conduct modelling to investigate which % population / % area can potentially be disturbed considering extent and duration without population consequences
- Use the most appropriate density estimates, e.g. spatial density surface should be retrieved/ used over a uniform density estimate (if available and robust).

Threshold specific recommendations

There are three key types of threshold that have been used in EIAs and HRAs to assess the potential for disturbance of marine mammals, which have different benefits and limitations. Specific recommendations relating to each of the disturbance assessment methods are outlined in the following sections.

Dose-response curves

We recommend the use of noise threshold based dose-response curves over fixed noise threshold over EDRs in order to obtain the predicted number of animals potentially disturbed (if those thresholds are robust and tailored to the given project).

It is recommended that:

- D/R curves should be developed for key species and sound sources that are lacking: e.g. piling and minke whale, common dolphin, bottlenose dolphin, grey seal, although we acknowledge that it might be harder for one species/ sound source than for the other
- D/R curves should be used where the species and sound type combination is available
- D/R curves should be used to assess the number of animals affected by behavioural disturbance but not for area-based assessment
- D/R curves should display 'dose' in a variety of relevant units, e.g. distance as well as SPL and unweighted and species weighted SELs to enable transferability to other projects and species
- D/R curves should use background-noise to determine the most appropriate lowest D/R level to use.

Fixed noise thresholds

With regards to fixed noise thresholds, it is recommended that:

- TTS thresholds should not be used as a proxy for disturbance, unless no other information is available. If TTS thresholds are used, then we recommend the use of those proposed in Table 5 of Southall et al. (2007). Note that these differ from those given for the determination of TTS-onset for auditory injury
- The Southall et al. (2019) TTS-thresholds should not be used as a proxy for disturbance
- The resulting predictions from fixed noise thresholds should be compared with those obtained from a D/R approach where possible to understand differences and to inform cases in which D/R cannot be applied.

Effective Deterrent Ranges

With regards to EDRs, it is recommended that:

- An EDR approach should primarily be applied when there is a need to assess disturbance in relation to a temporary habitat loss, with its application to the significance for individuals limited to occasions where other methods are not available
- EDRs for species other than harbour porpoise are developed (if this approach is applied for HRAs with a different species as the primary feature).
- Investigations are conducted into how to make the EDR approach more scientifically robust (e.g. a combined dose-response/EDR, field based collection of further/more up-to-date data)

- EDRs are adapted if more evidence becomes available as a consequence of changing emissions from sound sources (e.g. increase in hammer energy/ pile diameter/ UXO charge size and resulting increase in sound levels and impact ranges).
- EDRs are robustly informed where information is available (gap-analysis to be conducted), using a precautionary approach where evidence is missing.
- EDRs should not be used to determine the number of animals disturbed unless no other information is available.

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Appendix 1: Thresholds used for behavioural impact assessment

EDRs

JNCC EDRs for SACs

The EDRs recommended by JNCC (2020c) are to assess disturbance impacts against SAC conservation objectives and as such are considered further in the HRA section **Appendix 4: HRA Guidance** and Table 10.

Sound Protection Concept in Germany

The EDRs recommended by the German Sound Protection Concept ASCOBANS (2014) are to assess disturbance impacts against HRA conservation objectives and as such are considered further in the HRA section. Please see **Appendix 4: HRA Guidance.**

Fixed noise thresholds

This appendix briefly outlines some of the generic fixed noise thresholds that have been adopted for marine mammals.

NMFS (1995): Harassment Levels

In the US, under the 1994 Amendments to the Marine Mammal Protection Act, harassment is defined as any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild (Level B harassment). The threshold for Level B harassment is **160 dB re 1µPa SPL** from an impulsive sound source, and **120 dB re 1µPa SPL** from a non-impulsive/continuous sound source (NMFS 1995, 2005).

Kastelein et al. (2005): Discomfort threshold

Kastelein et al. (2005) subjected two captive porpoises to different sound sources to determine their behavioural responses and obtain a “discomfort” threshold where the discomfort zone was defined as the area around a sound source that harbour porpoise are expected to avoid. The discomfort thresholds obtained for the two porpoises were very similar to each other, but varied with sound source from an **SPL (with the power summed over four 1/3-octave bands 8,10,12.5 and 16 kHz) of 97 to 112 dB re 1 µPa**.

Nedwell et al. (2007): dB_{ht}

The dB_{ht}(*Species*) threshold was proposed by Nedwell et al. (2005) and validated by Nedwell et al. (2007) as a frequency weighted measure of the behavioural and auditory effects of underwater noise. This threshold approach uses a generalisation of the A-weighting approach that is used to take into account the hearing sensitivity of humans. Two specific dBht values have been in general use as fixed thresholds in assessments: **90 dB_{ht}(*Species*)** is defined by Nedwell et al. (2005) as a strong avoidance reaction by virtually all individuals. This is described as an “instinctive reaction” where animals will avoid the noise, and **75 dB_{ht}(*Species*)** is defined by Nedwell et al. (2005) as mild behavioural avoidance.

Southall et al. (2007): Behavioural response criteria

Southall et al. (2007) conducted a review of literature and provided a summary of the number of animals that responded to different received levels and ranked them using a behavioural severity scoring (Table 6). The severity scores categorize the effect of sound on marine mammals, with scores of zero to three used to categorise relatively minor and/or brief behavioural reactions, scores four to six for behavioural changes that have a higher potential to affect foraging, reproduction or survival, and scores seven to nine for changes that are considered likely to affect vital rates. Southall et al. (2007) provided thresholds for behavioural disturbance from single pulse noise sources, but did not go as far as to recommend specific thresholds for behavioural response from multiple pulse and non-pulsed noise sources, though they did provide some general comments on the limited literature available (Table 7). The authors highlight that the observed results in the literature are highly limited by uncertainty as to what constitutes a meaningful response. They also state that behavioural reactions are more variable, context dependent and less predictable than effects on hearing or physiology. The EIAs for some UK developments (e.g. Dogger Bank Creyke Beck A and B) have used the multi or single pulse severity scoring from Southall et al. (2007) to define “likely” and “possible” avoidance thresholds for different marine mammal hearing groups (Table 8) (Forewind 2013)

Table 6 Southall et al (2007): Severity scale for ranking observed behavioural responses of free-ranging marine mammals and laboratory subjects to various types of anthropogenic sound.

Response score[1]	Corresponding behaviors (Free-ranging subjects)[2]	Corresponding behaviors (Laboratory subjects)[2]
0	- No observable response	- No observable response
1	- Brief orientation response (investigation/visual orientation)	- No observable response
2	- Moderate or multiple orientation behaviors - Brief or minor cessation/modification of vocal behavior - Brief or minor change in respiration rates	- No observable negative response; may approach sounds as a novel object
3	- Prolonged orientation behavior - Individual alert behavior - Minor changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source - Moderate change in respiration rate - Minor cessation or modification of vocal behavior (duration < duration of source operation), including the Lombard Effect	- Minor changes in response to trained behaviors (e.g., delay in stationing, extended inter-trial intervals)
4	- Moderate changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source - Brief, minor shift in group distribution - Moderate cessation or modification of vocal behavior (duration ≈ duration of source operation)	- Moderate changes in response to trained behaviors (e.g., reluctance to return to station, long inter-trial intervals)
5	- Extensive or prolonged changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source - Moderate shift in group distribution - Change in inter-animal distance and/or group size (aggregation or separation) - Prolonged cessation or modification of vocal behavior (duration > duration of source operation)	- Severe and sustained changes in trained behaviors (e.g., breaking away from station during experimental sessions)
6	- Minor or moderate individual and/or group avoidance of sound source - Brief or minor separation of females and dependent offspring - Aggressive behavior related to noise exposure (e.g., tail/flipper slapping, fluke display, jaw clapping/gnashing teeth, abrupt directed movement, bubble clouds) - Extended cessation or modification of vocal behavior - Visible startle response - Brief cessation of reproductive behavior	- Refusal to initiate trained tasks
7	- Extensive or prolonged aggressive behavior - Moderate separation of females and dependent offspring - Clear anti-predator response - Severe and/or sustained avoidance of sound source - Moderate cessation of reproductive behavior	- Avoidance of experimental situation or retreat to refuge area (≤ duration of experiment) - Threatening or attacking the sound source
8	- Obvious aversion and/or progressive sensitization - Prolonged or significant separation of females and dependent offspring with disruption of acoustic reunion mechanisms - Long-term avoidance of area (> source operation) - Prolonged cessation of reproductive behavior	- Avoidance of or sensitization to experimental situation or retreat to refuge area (> duration of experiment)
9	- Outright panic, flight, stampede, attack of conspecifics, or stranding events - Avoidance behavior related to predator detection	- Total avoidance of sound exposure area and refusal to perform trained behaviors for greater than a day

Table 7 Proposed behavioural response criteria for individual marine mammals exposed to various sound types (collated from text in Southall et al 2007). LF = low frequency cetacean (e.g. minke whale), MF = mid-frequency cetacean (e.g. bottlenose dolphin), HF = high-frequency cetacean (e.g. harbour porpoise), PW = pinniped (e.g. harbour seal) in water and PA = pinniped in air.

Group	Single Pulse	Multiple pulses	Non-pulses
LF	$L_{p,pk}$ 224 dB re 1 μPa M-weighed SEL: 183 dB re 1 μPa²s (M_{lf})	Migrating bowhead whale: SPL RL 120 dB re 1 μPa Others: SPL RLs 140-160 dB re 1 μPa (grey whale, humpback whale, non-migrating bowhead whale)	No/very limited response: SPL RLs 90-120 dB re 1 μPa Increasing probability of avoidance and other behavioural effects: SPL RLs 120-160 dB re 1 μPa
MF	$L_{p,pk}$ 224 dB re 1 μPa M-weighed SEL: 183 dB re: 1 μPa²s (M_{mf})	No clear tendency for increasing probability and severity of response with increasing RL. Silence vocal behaviour: SPL RLs ~80-90 dB re 1 μPa (sperm whale) No response: SPL RLs 120-180 dB re: 1 μPa (beluga whale & false killer whales)	No clear conclusion about SPL RLs coincident with various behavioural responses. Behavioural response in some individuals: SPL RLs 90-120 dB re 1 μPa No response in some individuals: SPL RLs 120-150 dB re 1 μPa
HF	$L_{p,pk}$ 224 dB re 1 μPa M-weighed SEL: 183 dB re: 1 μPa²s (M_{hf})	Not possible to present any data on behavioural responses of high-frequency cetaceans as a function of received levels of multiple pulse	Sensitive: SPL RLs ~90-120 dB re 1 μPa (harbour porpoise) Profound and sustained avoidance: SPL RL >140 dB re 1 μPa (harbour porpoise)
PW	$L_{p,pk}$ 212 dB re 1 μPa M-weighed SEL: 171 dB re 1 μPa²s (M_{pw})	Limited response: SPL RLs ~150-180 dB re 1 μPa Likely response: SPL RLs >190 dB re 1 μPa (ringed seals)	Limited data Generally no strong response: SPL RLs ~90-140 dB re 1 μPa

Table 8 Likely and possible avoidance thresholds used in the Dogger Bank Creyke Beck Environmental Statement – derived from Southall et al. (2007) for low frequency cetacean (e.g. minke whale) (LF) from the multiple pulses severity scoring behavioural disturbance (SPL converted to SEL_{ss} by subtraction of 8 dB, for mid-frequency cetacean (e.g. bottlenose dolphin) (MF) from the multiple pulses severity scoring behavioural disturbance (SPL converted to SEL_{ss} by subtraction of 10 dB) and pinniped (e.g. harbour seal) in water (PW) from the single pulse behavioural disturbance.

Group	Likely avoidance	Possible avoidance
LF*	SEL_{ss} 152 dB re 1 μPa²s	SEL_{ss} 142 dB re 1 μPa²s
MF ˣ	SEL_{ss} 170 dB re 1 μPa²s	SEL_{ss} 160 dB re 1 μPa²s
PW “	M_{pw} weighted 171 dB re 1 μPa²s	Not defined

LF = low frequency cetacean (e.g. minke whale), MF = mid-frequency cetacean (e.g. bottlenose dolphin), PW = pinniped (e.g. harbour seal) in water

* Southall et al. (2007) Multiple pulses severity scoring behavioural disturbance (RMS SPL converted to pulse SEL by subtraction of 8dB).

× Southall et al. (2007) Multiple pulses severity scoring behavioural disturbance (RMS SPL converted to pulse SEL by subtraction of 10dB).
“Southall et al. (2007) Single pulse behavioural disturbance.

TTS-onset Thresholds

Given the lack of guidance on behavioural thresholds, EIAs have sometimes used the TTS-onset threshold as a proxy for disturbance. The recommended TTS-onset thresholds have evolved from initial guidelines provided by NMFS (1995) to the most recent updated recommendations in Southall et al. (2019) (Table 9). It is important to understand that TTS and behavioural disturbance are not interchangeable. Whilst Southall et al. (2007) stated that in the absence of data on the behavioural responses to impulsive noise, the TTS-onset threshold *could* be used as a proxy for a behavioural threshold, this was not recommended for multiple pulses and nonpulses, as data for these sound types are available. It is important to note that the recommended cetacean TTS-thresholds of Southall et al. (2007) given in their table 5 are based on the TTS-onset values of one beluga exposed to a single pulse and extrapolated to other cetacean species. The use of TTS-onset thresholds is therefore to be used with caution and not appropriate as a proxy behavioural response for the assessment of disturbance from multiple pulse sound sources such as pile driving.

Table 9 Marine mammal TTS-onset thresholds recommended in guidance and literature

Reference	**Marine mammal group**	**TTS-Threshold**
NMFS (1995)	Cetacean	SPL180 dB re 1µ Pa
NMFS (1995)	Pinnipeds	SPL 190 dB re 1µ Pa
UK MOD (2002)	All	75 dB above Threshold of Hearing for 8 hours exposure
NMFS (2006)	All	SEL 195 dB re 1µ Pa^2s
Southall et al. (2007)	Cetacean	$L_{p,pk}$ 224 dB re 1µ Pa SEL(m-weighted)183 dB re 1µ Pa^2s
Southall et al. (2007)	Pinniped	$L_{p,pk}$ 212 dB re 1µ Pa SEL(m-weighted)171 dB re 1µ Pa^2s
Southall et al. (2019) (non-impulsive)	LF Cetacean	SEL(weighted)179 dB re 1 µPa^2s
Southall et al. (2019) (non-impulsive)	HF Cetacean	SEL(weighted)178 dB re 1 µPa^2s
Southall et al. (2019) (non-impulsive)	VHF Cetacean	SEL(weighted)153 dB re 1 µPa^2s
Southall et al. (2019) (non-impulsive)	PCW	SEL(weighted)181 dB re 1 µPa^2s
Southall et al. (2019) (inpulsive)	LF Cetacean	SEL(weighted)168 dB re 1 µPa^2s $L_{p,pk}$ 213 dB re 1 µPa
Southall et al. (2019) (inpulsive)	HF Cetacean	SEL(weighted)170 dB re 1 µPa^2s $L_{p,pk}$ 224 dB re 1 µPa

Southall et al. (2019) (inpulsive)	VHF Cetacean	SEL(weighted)140 dB re 1 μPa^{2}s $L_{p,pk}$ 196 dB re 1 μPa
Southall et al. (2019) (inpulsive)	PCW	SEL(weighted)170 dB re 1 μPa^{2}s $L_{p,pk}$ 212 dB re 1 μPa

Lucke et al (2009): Porpoise adverse reaction

A study conducted by Lucke et al. (2009) on harbour porpoise detailed behavioural responses to an airgun source. The study found that the porpoise showed an aversive behavioural reaction to the stimuli at received **SPL_{pp} >174 dB re 1 μPa** or an **SEL of 145 dB re 1 μPa^{2}s**, with the SEL being cumulated over one airgun impulse (single strike SEL). While this study was based on a single captive porpoise, various field studies have shown support for this threshold: for example, Brandt et al. (2016) found onset of a behavioural reaction at SEL values in the range of 140–152 dB re 1 μPa^{2}s from pile driving and Thompson et al. (2013a) observed similar avoidance at levels of 145–151 dB re 1 μPa^{2}s for a seismic airgun.

Tougaard et al. (2015): Avoidance thresholds

Following on from the Southall et al. (2007) proposed noise exposure criteria, Tougaard et al. (2015) reviewed additional TTS and behavioural response studies to propose further edits to the noise criteria. The studies included responses of harbour porpoise to different noise sources, including pile driving, seal scarers and pingers. They indicated a decreasing threshold of response with increasing signal peak frequency. Thus, the behavioural reactions were approximately parallel to the audiogram but offset by 40–50 above the hearing threshold. The authors therefore proposed an avoidance reaction (negative phonotaxis) threshold at **L_{eq}-fast 45 dB above the hearing threshold**.

Heinis et al. (2019): Disturbance area

In order to determine the area disturbed by impulsive sound by a single pile strike to assess the cumulative effects of offshore wind farm construction on harbour porpoises in Dutch waters, a threshold value of **143 dB re 1 μPa²s** was adopted. This threshold value was based on results obtained by Brandt et al. 2018, who found a decline of harbour porpoise detection rate above this limit, when looking at the first seven wind farms constructed in German waters. A previous study of Heinis et al in 2015 used a threshold of **140 dB re 1 μPa²s**, which was adopted as conservative approach in the 2019 study. Note that 140 dB re 1 μPa²s was also used in the German Sound Protection Concept (ASCOBANS 2014), based on a various studies in German and Danish waters, to support their EDR.

Dose-response curves

Thompson et al. (2013b): Porpoise D/R curve piling noise

Thompson et al. (2013b) produced a harbour porpoise dose-response curve (and applied it to harbour seal) for both range and dBht (Figure 15) based on the piling at the Horns Rev II Offshore Windfarm in Denmark (Brandt et al. 2011). Figure 15 shows the harbour porpoise occurrence (mean porpoise positive minutes from CPODs (from Brandt et al., 2011)) in the hour after the event; relationship for the line of best fit (deviance = 4.19; d.f. = 1; P<0.05; Intercept = 3.9 (se = 2.77; Range = −0.32 (SE = 0.23)). The best fitted relationship is shown as a solid line. Standard errors were used to provide confidence limits around this relationship. However, because small sample sizes resulted in the upper bound showing almost no variation across the range of distances studied, instead an upper bound was produced for the relationship by weighting the line to include all data points. The lower bound is based upon the standard error of the coefficients.

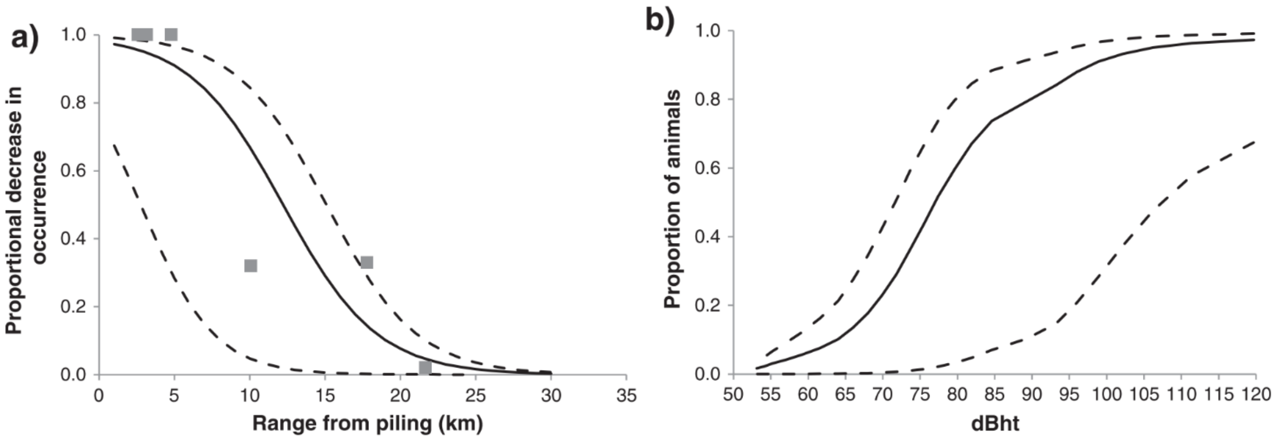

Figure 15 Thompson et al. (2013b): a) Predicted relationship between range from the Horns Rev II piling operation and the proportional decrease in harbour porpoise occurrence b) The relationship between dBht (harbour porpoise) and the predicted proportion of animals excluded from the area (using the upper, best and lower fitted relationship from a).

Neart na Gaoithe (2018): Porpoise D/R curve piling noise

The Neart na Gaoithe impact assessment (Neart na Gaoithe 2018) created a harbour porpoise dose-response curve (Figure 16) based on studies conducted at various offshore windfarms in Germany (Brandt et al. 2016).

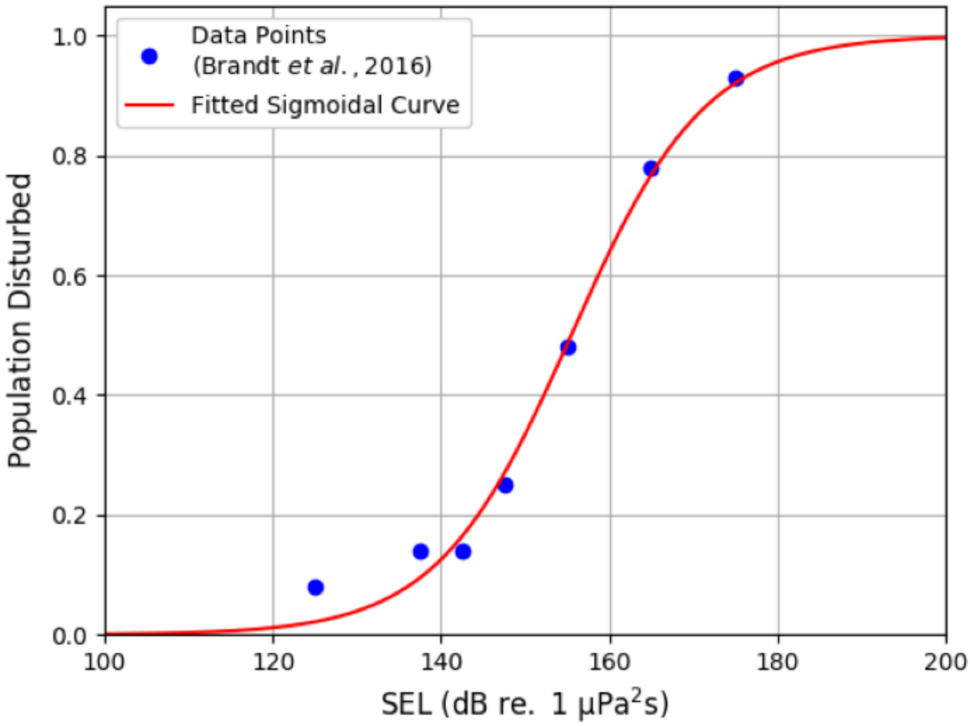

Figure 16 Neart na Gaoithe (2018): Behavioural response curve used for assessing potential behavioural disturbance to marine mammals.

Graham et al. (2017a): Porpoise D/R curve piling noise

Graham et al. (2017a) created a harbour porpoise dose-response curve based on detection probability during Phase 1 of the Beatrice Offshore Windfarm in Scotland (Figure 17). Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence (DPH) exceeded a threshold of 0.5. Points show actual response data.

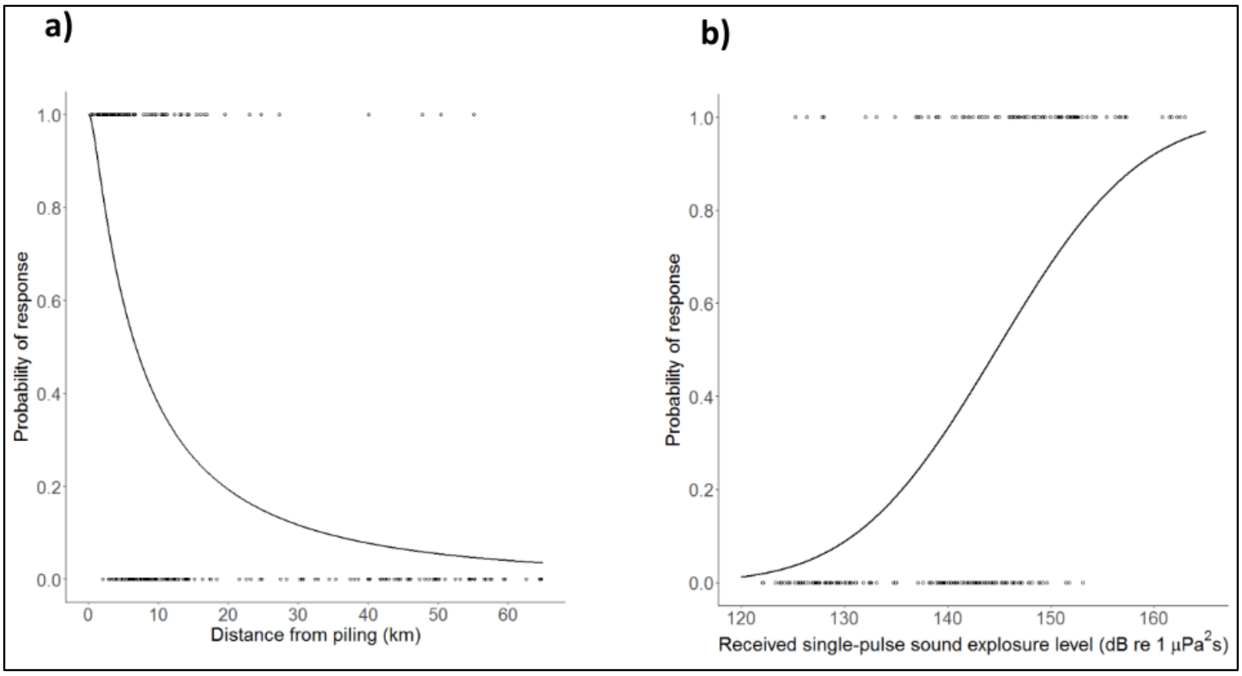

Figure 17 Graham et al. (2017): The probability of a harbour porpoise response in relation to a) distance from piling and b) received single-strike SEL.

Graham et al. (2019): Porpoise D/R curve piling noise

Graham et al. (2019) produced a dose response curve for both range and SEL (Figure 18) based on the first location piled and the last location piled at the Beatrice Offshore Windfarm in Scotland. Figure 18 shows predictions for the first location piled (solid navy line) and the final location piled (dashed blue line), assuming the number of AIS vessel locations within 1 km = 0; confidence intervals (shaded areas) were estimated for uncertainty in fixed effects only. Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence (DPH) exceeded a threshold of 0.5. Points show actual response data for the first location piled (filled navy circles) and the final location piled (open blue circles).

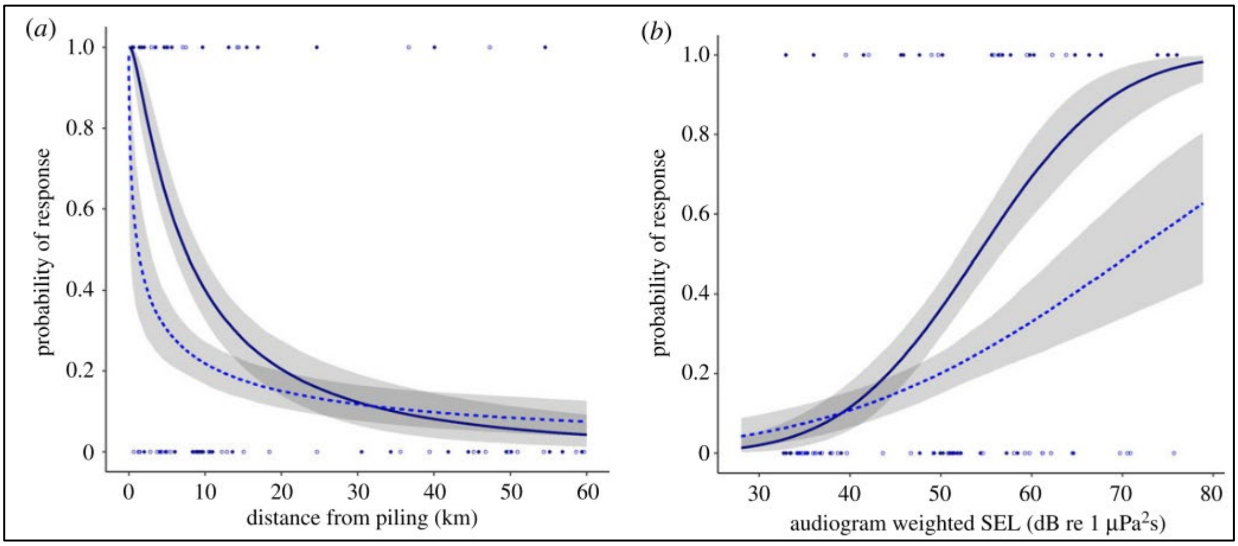

Figure 18 Graham et al (2019): The probability of a harbour porpoise response (24 h) in relation to the partial contribution of (a) distance from piling and (b) audiogram-weighted received single-pulse SEL.

Russell and Hastie (2017): Harbour seal D/R curve piling noise

Russell and Hastie (2017): produced a dose-response curve for harbour seal based on the data collected at the Lincs Offshore Windfarm in England Russell and Hastie (2017) (Russell et al. 2016) (Figure 19). It was conservatively assumed that 100% displacement occurs at received levels above an SEL of 165 dB re 1 μPa²s.

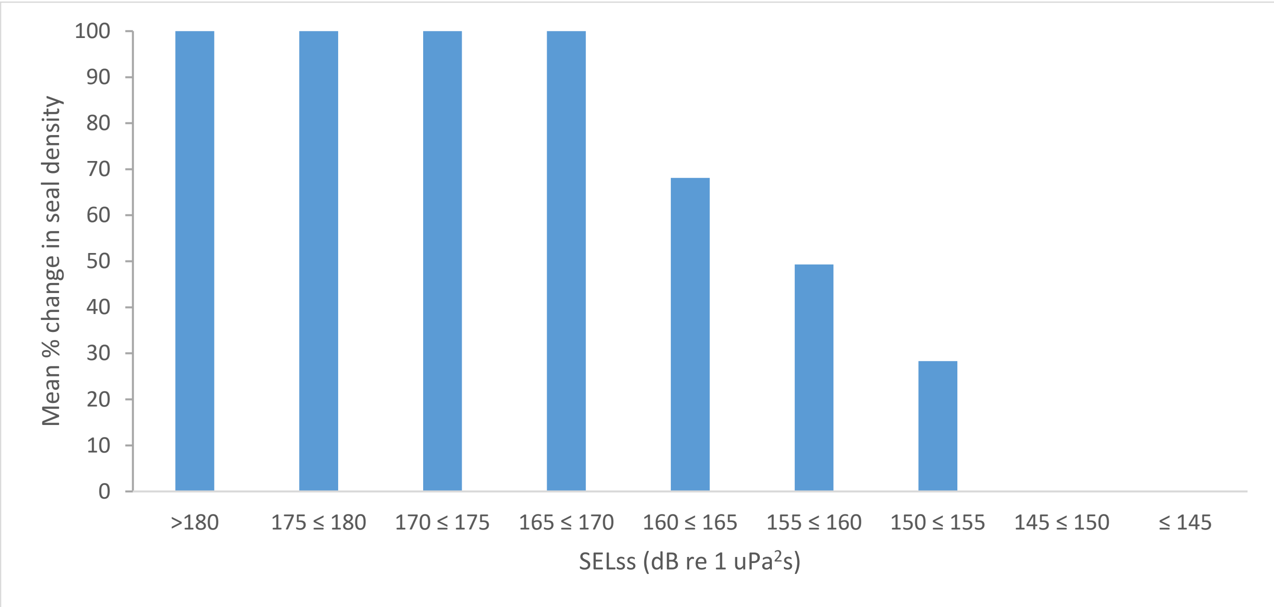

Figure 19 Russell and Hastie (2017): Predicted proportion of harbour seals responding in relation to depth averaged received levels.

Whyte et al. (2020): Harbour seal D/R curve piling noise

Whyte et al. (2020): Updated the harbour seal dose-response curve using data from (Russell et al. 2016) but with an improved propagation model (Figure 20). It was conservatively assumed that all harbour seals respond at SEL_{ss} >180 dB re 1 μPa²s; however, there were no data to support this.

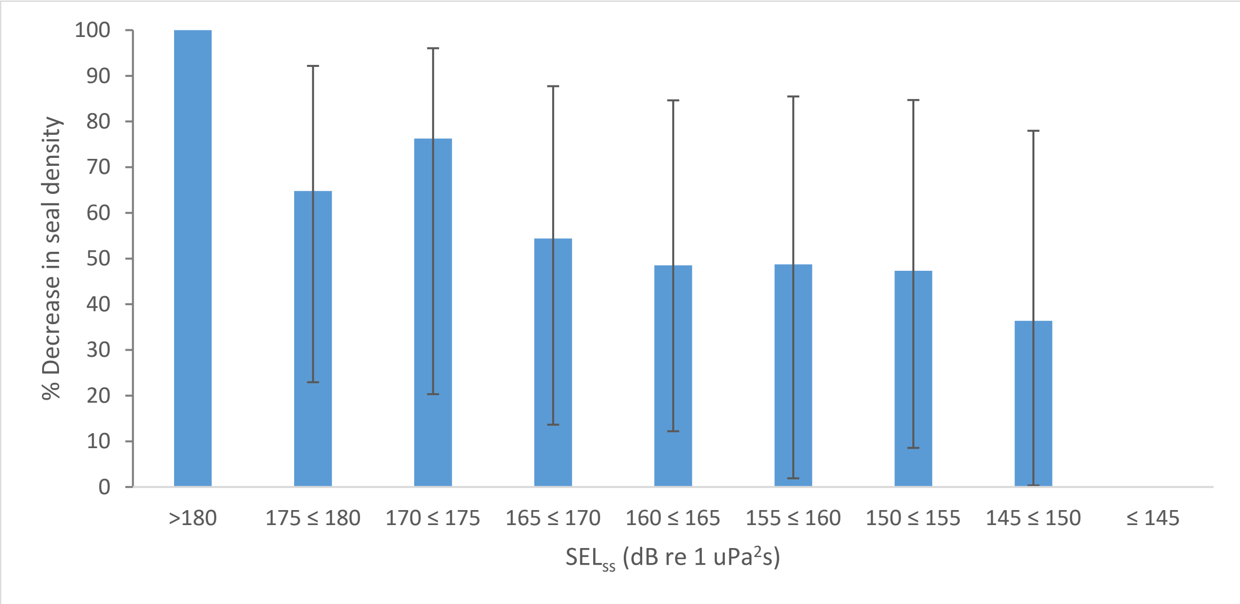

Figure 20 Whyte et al (2020): Predicted decrease in harbour seal density in relation to predicted sound exposure levels.

Appendix 2: Sound Sources

In the following section, the noise emission of the different sound sources considered in EIAs are described, and studies supporting the potential impact of these sources on marine mammals are given, as well as noise thresholds advised and/or used in EIAs.

Vessels

Description of sound

Vessels produce non-impulsive, continuous noise, but the sound pressure level and the frequency range depend on the vessel type and their activity. In general, vessels generate noise in the low frequency range between 10-100 Hz (Erbe et al. 2019). However, noise is also generated at higher frequencies (tens of kHz) (Veirs et al. 2016). The frequency of ship noise can vary quite considerably, as large oil tankers generate louder, lower frequency noise, when compared with higher frequency sound produced by tourism vessels and recreational boating. Recent investigation into vessel noise frequency bands indicates that ship noise can elevate ambient noise levels even at frequencies of 125 kHz (Hermannsen et al. 2014).

Evidence base for behavioural impact

Noise produced by vessels has been shown to impact the behaviour of marine mammals of various species, where changes in vocalisation and behavioural state have been observed, in addition to displacement of animals from areas where ships are present. There are considerable concerns regarding the impacts of shipping on marine mammals, due to the increase of noise levels in the marine environment over the past decades, and the overlap of the frequency spectrum of the shipping noise with the species' hearing range and vocalisation repertoire. This is particularly true for baleen whales that communicate over long distances at low frequencies, but anthropogenic masking and disturbance also occurs in odontocetes and pinnipeds. The extent to which behavioural disturbance occurs appears to be species-specific, but has been observed for a range of species worldwide.

Harbour porpoise

Disturbance of harbour porpoise by vessels has been recorded throughout European waters, and Passive Acoustic Monitoring has highlighted disruptions of foraging behaviour. Evidence of harbour porpoise disturbance is exemplified through reductions in local density estimates and sightings, changes in swimming behaviour, and differences in vocalisations. In a large scale study of harbour porpoise density in UK waters, including the North Sea MU and the Irish Sea MU, increased vessel activity was associated with lower porpoise densities. Conversely, in North West Scottish waters, shipping had little effect on the density of individuals (Heinänen and Skov 2015).

The advancement of telemetry has provided the opportunity to tag individuals to identify fine-scale responses to stressors in the marine environment. Between 2012-2016, seven harbour porpoises were tagged in a region of high shipping density in the inner Danish waters and Belt seas. High noise levels coincided with erratic behaviour including 'vigorous fluking', bottom diving, interrupted foraging, and the cessation of vocalisations. Four out of six of the animals that were exposed to noise levels above 96 dB re 1 μPa (16 kHz third octave levels) produced significantly fewer buzzes with high quantities of vessel noise. In one case, the proximity of a single vessel resulted in a 15 minute cessation in foraging (Wisniewska et al. 2018).

Behavioural responses of harbour porpoises to vessel noise have also been observed in more controlled conditions. In the Fjord & Belt Centre in Denmark, four harbour porpoises inhabiting a net-pen were often exposed to ship noise from nearby transiting vessels. Simultaneously recording the vessel noise and monitoring the behaviour of the individuals demonstrated that high-frequency components of vessel noise, even at low levels, elicited strong behavioural response known as 'porpoising'. During 80 high quality recordings of boat noise, this stereotypical disturbance behaviour was observed in 27.5% of cases (Dyndo et al. 2015).

Furthermore, land-based surveys were used to observe the surfacing behaviour of harbour porpoise in relation to vessel traffic. In Swansea Bay, Wales, 729 hours of surveying found a significant correlation between porpoise sightings and the number of vessels present. 26% of the interactions were considered to be negative (moving away or prolonged dives), occurring within distances of up to 1 km between the animal and the vessel. However, proximity to the source was found to be important, with the greatest reaction occurring just 200 m from the vessel. The type of vessel was also relevant, as smaller motorised boats (Jet-ski, speed boat, small fishing vessels), were associated with more negative behaviours than larger cargo ships, although this type of vessel was a less common occurrence (Oakley et al. 2017).

Recently, behaviour-based modelling has suggested that the presence of ships may have a negative impact on the Danish population of harbour porpoise in conditions where food sources are low. However, when comparing the theoretical impact of ship presence versus bycatch, the latter was found to have a greater effect on population size and Nabe-Nielsen et al. (2014) suggest that conservation efforts should therefore focus more closely on this issue.

Data collected during windfarm construction have demonstrated that porpoise detections around the pile driving site decline several hours prior to the start of pile driving, and it is assumed that this is due to the increase in other construction related activities and vessel presence in advance of the actual pile driving (Brandt et al. 2018, Benhemma-Le Gall et al. 2020).

In conclusion, for harbour porpoise, changes in behaviour and presence are likely indications of disturbance in the presence of vessel noise. Behavioural observations may be used by recording activity during times of low vessel presence, to identify changes such as increased fluking, prolonged dives and directed movement away from the sound source. This displacement can also be exemplified by surveying for harbour porpoise in an area with variable levels of vessel traffic, where reductions in local density suggest disturbance from the surrounding area. The type of vessel impacts the frequency distribution of the produced sound, which may be important for this species as high-frequency components have been linked to negative behavioural responses, even at low levels.

Bottlenose dolphins

As a globally distributed species that often occupies coastal waters, bottlenose dolphins are exposed to varying levels of shipping noise around the world. In addition, a combination of their abundance and sociable nature facilitates their exposure not only to cargo and commercial vessel noise, but also to disturbance from directed tourism platforms.

A study of Indo-Pacific bottlenose dolphin habitat occupancy along the coast of Western Australia found dolphin density to be negatively affected by vessels at one site but no significant impact at the other (Marley et al. 2017a). It is hypothesised that as the latter habitat is a known foraging site, perhaps the quality of the habitat impacts the behavioural response to disturbance. Differences in water depth were also hypothesised as important, as the site that was characterised by changes in dolphin density with vessel activity was more shallow than the other location (average depths of 1 m and 13 m respectively). Dolphins have been demonstrated to avoid shallow waters as a predator avoidance response, and similar responses have resulted from vessel disturbance (Lusseau 2006).

Aside from reductions in bottlenose dolphin density, in the same area of Western Australia, increased vessel presence was also associated with significantly increased swimming speeds for individuals when resting or socialising. In addition, animals exposed to high levels of shipping traffic were found to generally spend more time travelling and less time resting or socialising. Finally, the characteristics of their whistles were found to change with increased broadband exposure, with the greatest variation occurring in the presence of low frequency noise (Marley et al. 2017b). These findings are further supported by a study of common bottlenose dolphins in Galveston Ship Channel (Piwetz 2019). The presence of boats was associated with significantly less foraging and socialising activity states. For this population, a significant increase in swimming speeds was observed during the presence of recreational and tourism vessels and shrimp trawlers.

For common bottlenose dolphins in the North Sea, while vessel noise was not investigated, boat presence was associated with a short-term reduction in foraging activity. Susceptibility of disturbance was variable depending on the location and year, suggesting circumstantial impacts of vessel noise on bottlenose dolphins. Animals resumed foraging after the vessel had travelled through the area (Pirotta et al. 2015). This variability in disturbance from vessels is also observed in Aberdeen harbour, a busy shipping area that is frequently occupied by bottlenose dolphins (Pirotta et al. 2013).

Grey seals

Recently, a telemetry study that included the tagging of 28 harbour seals in the UK found high exposure levels of harbour seals to shipping noise (Jones et al. 2017). 20 individuals may have experienced a temporary threshold shift due to cumulative sound exposure levels exceeding the TTS-threshold for pinnipeds exposed to continuous underwater noise (183 dB re 1 $\mu Pa^2 s$) proposed by Southall et al. (2007). Overlap between seals and vessel activity most frequently occurred within 50 km of the coast, and in proximity to seal haul-outs. Despite the distributional overlap, and high cumulative sound levels, there was no evidence of reduced presence as a result of vessel traffic (Jones et al. 2017). A combined study of grey seal pup tracks in the Celtic Sea and adult grey seals in the English channel found that no animals were exposed to cumulative shipping noise that exceeded thresholds for TTS (using the Southall et al. 2019 thresholds) (Trigg et al. 2020).

A study of grey seal pupping beaches around Ramsey Island in Pembrokeshire found that disturbance occurred when vessels were closer than 150 m to seal locations. While the disturbance from noise cannot be quantified here, and this example is specific to disturbance from a haul out site, the ability of vessels to elicit a response in grey seals is still notable (Strong and Morris 2010). On the Northwest coast of Ireland, a study of vessel traffic and marine mammal presence found grey seals sightings to decrease with increased vessel activity in the surrounding area (Anderwald et al. 2013).

Common / Risso's dolphins

In common dolphins, the presence of vessels has been linked to changes in behavioural states, associated with disturbance. Foraging and resting activity was significantly disrupted by vessel activity, and returns to foraging activity took significantly longer than returns to other states (Stockin et al. 2008, Meissner et al. 2015). Marine mammal monitoring during the construction of a pipeline in Northwest Ireland found an increase in vessel numbers to be linked to reduced presence of common dolphins. However, seasonal patterns of occurrence were also observed, suggesting perhaps only short-term impacts of vessel disturbance (Culloch et al. 2016).

Minke whale

There are few studies on the impacts of ships and vessel noise on minke whales; however, Christiansen et al. (2013) found increased interactions with boats resulted in a decrease in foraging activity, exemplified by shorter dives and changes in movement patterns. In addition, by analysing the respiration rate of minke whales, energy expenditure for minke whales was estimated to be 28% higher during boat interactions, regardless of swim speed. Swim speeds also increased in the presence of whale watching vessels, and these combined physiological and behavioural changes are thought to represent a stress response, although noise levels were not measured and responses were therefore related to vessel presence (Christiansen et al. 2014).

Thresholds advised and/or used in EIAs

It is difficult to quantify the extent to which vessel noise should and can be mitigated to reduce the disturbance of marine mammals, as reported noise level and dose-response studies for this are generally lacking. Thresholds for disturbance through vessel noise have been described as distances at which disturbance occurred (e.g. disturbance of harbour porpoise ranging from 200 m to 7 km from vessels (Tougaard et al. 2015)), and fixed sound pressure levels, for example behavioural response onset of harbour porpoise has been described at a mean level of 123 dB re 1 µPa (M-weighted, RMS) (Dyndo et al. 2015). While dose-response curves for vessels have only been created for killer whales (Joy et al., 2019), literature points towards an increasing reaction to vessel noise with increasing noise levels or distance to the sound source also for other species (e.g. Oakley et al. 2017). Some studies also suggest that the reaction of the animals is frequency dependent, as, e.g., harbour porpoises react differently to different vessel types (Wisniewska et al. 2018).

In relation to vessel noise, there are only a few source-specific thresholds for disturbance of marine mammals. However, some EIAs implement general thresholds for vessel noise that have previously been derived for continuous noise sources:

- Disturbance threshold for harbour porpoise by vessel density (80 vessels/day) (Heinänen and Skov 2015)
- Dose-response function for vessel noise for killer whales (Joy et al. 2019)
- Level B harassment for non-impulsive noise, SPL120 dB re 1 µPa (NMFS 2005)
- 75 and 90 dB_{ht}(species) mild and strong avoidance (Nedwell et al. 2007)
- Likely and possible avoidance levels (Southall et al. 2007)
- Harbour porpoise behavioural response (Lucke et al. 2009)

Dredging

Description of sound

Dredging can be described as a continuous broadband sound source, with the main energy below 1 kHz. However, the frequency and sound pressure level can vary considerably depending on the equipment, activity, and environmental characteristics (Todd et al. 2015). The source level (SPL at 1 metre from the sound source) of dredging has been described to vary between 172-190 dB re 1 µPa with a frequency range of 45 Hz to 7 kHz (Evans 1990, Thompson et al. 2009, Verboom 2014).

Evidence base for behavioural impact

Harbour porpoise

A preliminary report on the impacts of dredging on harbour porpoises has modelled the estimated noise levels to predict the potential for TTS and avoidance behaviour. It was concluded that dredging at a source level of 184 dB re 1 µPa at 1 m would result in avoidance up to 5 km from the dredging site (Verboom 2014). Conversely, (Diederichs et al. 2010) found much more localised impacts of dredging on harbour porpoises. Passive Acoustic Monitoring during the extraction of sand near Sylt suggest at least short term avoidance (~3 hours) at distances of up to 600 m from the dredging vessel, but no significant long term impacts were observed (Diederichs et al. 2010). More recently, modelling of the potential impacts of dredging using a case study of the Maasvlatke port expansion has been conducted to identify the potential ecological risks associated with such activity. Interestingly, acoustic propagation models were conducted using two sets of acoustic parameters (assuming maximum source levels of 192 dB re 1 µPa), one of which predicted a disturbance range of 400 m, while the more conservative approach predicted avoidance of harbour porpoise up to 5 km from the site (McQueen et al. 2020).These findings encapsule the disturbance ranges exhibited in previous studies, highlighting the importance of site specific information for the potential disturbance of harbour porpoise by dredging.

Bottlenose dolphins

In Aberdeen Harbour, bottlenose dolphins are known to exhibit foraging behaviour and occur in high densities, despite its reputation as a busy area for both construction and vessel traffic. However, increased dredging activity in the area was associated with a reduction in bottlenose dolphin presence in the harbour, and during the initial dredge operations, bottlenose dolphins were absent for five weeks (Pirotta et al. 2013). Similarly, in Western Australia a study of vessel traffic and dredging on Indo-pacific bottlenose dolphins found no individuals present on days when backhoe dredging occurred. However, there were only 12 occurrences of dredging over the study period, and dolphins were only recorded during 23% (18 out of 78) of the surveys in this area (Marley et al. 2017a).

Grey Seals

Thus far there has been little investigation into the potential for dredging activity to cause disturbance in pinnipeds. In one study on the impacts of dredging, Hawaiian monk seals showed no reaction to nearby dredge activity (MMC et al. 2002). However, based on the generic threshold of behavioural avoidance of pinnipeds (140 dB re 1 μPa SPL) (Southall et al. (2007), acoustic modelling of dredging has recently been used to demonstrate that disturbance could be caused to individuals between 400 m to 5 km from site (McQueen et al. 2020).

Common / Risso's dolphins

There is currently no information available on the impacts of dredging for common dolphins and Risso's dolphins.

Minke whale

While there is no dredging-specific research available on the disturbance of minke whales, along the coast of northwest Ireland, construction related activity (including dredging) has been linked to reduced harbour porpoise and minke whale presence (Culloch et al. 2016).

Thresholds advised and/or used in EIAs

Dredging noise occurs at relatively low frequencies, but at high sound pressure levels, and subsequently has been found to cause disturbance in a range of marine mammal species. Currently, disturbance from dredging is reported to occur between distances of 400 m - 5 km for high-frequency cetaceans and pinnipeds, with little information available on impact ranges for bottlenose dolphins. The SPLs reported for dredging are expected to cause disturbance but the avoidance threshold appears to be both site and species specific.

Within EIAs, the thresholds for dredging are generally derived from evidence of disturbance from non-impulsive sound sources:

- Level B harassment for impulsive noise (Fixed SPL 160 dB re 1 μPa) (NMFS 2005)
    - 75 and 90 dB_{ht}(species) mild and strong avoidance (Nedwell et al. 2007)
    - Likely and possible avoidance levels (Southall et al. 2007)

- Harbour porpoise behavioural response to continuous noise (Fixed SEL 145 dB re 1 μPa) (Lucke et al. 2009)
- Harbour porpoise behavioural response to continuous noise (Fixed $L_{p,pk}$ 174 dB re 1 μPa (Lucke et al. 2009)

Drilling

Description of sound

The continuous sound produced by drilling has been likened to that produced by dredging activity; low frequency noise caused by rotating machinery (Greene 1987). Recordings of drilling at the North Hoyle offshore windfarm suggest that the sound produced is tonal, with a fundamental frequency at 125 Hz, but harmonics were detected up to 8 kHz (Nedwell et al. 2003). It has been described as a short-term, non-impulsive sound source, with noise levels at 750m from the source estimated to be between 92- 156 dB re 1 μPa rms (NIRAS and SMRU Consulting 2019).

Evidence base for behavioural impact

There is little information available specifically on the potential disturbance of marine mammals by drilling activity. The research that is currently available was conducted at least 20 years ago, but it is suggested that noise from drilling may cause disturbance for at least some species of marine mammals. A survey of the literature suggests evidence of disturbance of baleen whales, for example drilling and dredging playback experiments found half of the exposed bowhead whales responded to noise levels of 115 dB re 1 μPa, and in some cases, calling, foraging and dive patterns were altered (Richardson and Wursig 1990).

In addition to evidence of disturbance of bowhead whales, there is some literature that suggests grey whales also exhibit avoidance behaviour in proximity to drilling activity. Playback experiments of drilling and industrial noise found that the probability of avoidance increased with increased noise levels. At 122 dB re 1 μPa, 90% of individuals exhibited avoidance behaviour in the form of diverted migration tracks (Malme et al. 1984). More recently, the effects of exploratory drilling were investigated for bowhead whales in the Beaufort Sea. Increasing noise levels were associated with a change in calling rates; specifically an increase in calling rate occurred which eventually plateaued and declined as noise continued to increase. It is suggested that the eventual cessation or decline in calling could relate to an abandoned attempt to overcome masking (Blackwell et al. 2017).

Thresholds advised and/or used in EIAs

Based on sparse literature, it has been suggested that the impacts of drilling may contribute to marine mammal disturbance at distances of between 10 – 20 km, depending on the species and environmental conditions (Greene Jr 1986, LGL and Greeneridge 1986, Richardson and Wursig 1990). However, there is currently no information available for our main species of interest in Welsh waters, and drilling is often grouped under industrial or construction noise in its acoustic features. If drilling has similar properties as dredging activity, disturbance of marine mammals could realistically occur between 5 – 10 km from the noise source.

As a result of the few specific studies on the effects of drilling noise on marine mammals, a range of thresholds are implemented that may result in disturbance from drilling activity:

- Level B harassment for non-impulsive noise (Fixed SPL 120 dB re 1 µPa) (NMFS 2005)
- 90 dB_{ht}(species) strong avoidance (Nedwell et al. 2007)
- Likely and possible avoidance levels (unweighted SELs) (Southall et al. 2007)
- TTS-onset thresholds for seals (SEL 183 dB re 1 µPa^{2}s) (Southall et al. 2007)
- Harbour porpoise behavioural response to continuous noise (Fixed SEL 145 dB re 1 µPa^{2}s) (Lucke et al. 2009)
- Harbour porpoise behavioural response to continuous noise (Fixed $L_{p,pk}$ 174 dB re 1 µPa (Lucke et al. 2009)

Seismic

Description of sound

Seismic surveys are often used in the marine environment to explore sediment layers by creating high pressure air, and a loud impulsive noise. While there are several types of equipment used in geophysical surveys, focus here is placed on airguns, as they are the most common (Hartley Anderson Ltd 2020). Seismic airguns create a stream of low frequency, impulsive sound, with the main energy centred around 200 Hz; however, higher frequencies of 10,000 Hz can also be produced. Thompson et al. (2013a) recorded received $L_{p,pk\text{-}pk}$ of 165–172 dB re 1 µPa and SELs between 145–151 dB re 1 µPa^{2}s.

Evidence base for behavioural impact

Harbour porpoise

The research on harbour porpoise disturbance from seismic surveys has produced variable results. A study of tagged harbour porpoises in the inner Danish waters has shown large variability between individual responses to an airgun stimulus (van Beest et al. 2018). Of the five porpoises tagged and exposed to airgun pulses at ranges of 420 – 690 m (SEL 135 - 147 dB re 1 µPa^{2}s), one individual showed rapid and directed movements away from the source. Two individuals displayed shorter and shallower dives immediately after exposure and the remaining two animals did not show any quantifiable response. In the central Moray Firth, northeast Scotland, behavioural response to seismic activity was recorded up to 10 km from the noise source, with received SPL_{pkpk} of 165–172 dB re 1 µPa and SELs of 145–151 dB re 1 µPa^{2}s. However, the effects of the disturbance appeared to be short-term, with animals returning to the site within a few hours of the cessation of surveying (Thompson et al. 2013a). Conversely, further acoustic analysis from the same survey found differences in echolocation activity linked to seismic activity. During geophysical surveys with SELs of 150–165 dB re 1 µPa^{2}s, the probability of recording a buzz, vocalisation linked to foraging activity, decreased by 15%. In addition, the likelihood of buzzing increased with distance from the sound source, suggesting the importance of received levels (Pirotta et al. 2014). The probability of detection increased significantly from 0.15 at the source, to 0.35 at distances of 40km from seismic activity, demonstrating the large geographic range at which disturbance may have occurred.

Further research into the impacts of seismic surveys on harbour porpoise using PAM suggests no long term displacement from survey areas, but does support previous findings of changes in echolocation behaviour. In the North Sea, declines in echolocation activity were detected up to 12 km from seismic activity, which could be representative of either a temporary displacement of animals, or a change in echolocation behaviour that could indicate reduced foraging (Sarnocinska et al. 2019). Equally, a large scale study of marine seismic surveys throughout the UK and adjacent waters identified differences in harbour porpoise detections during seismic activity. Detection rates of harbour porpoise were computed using a combinations of visual surveys and PAM, and were found to be significantly lower during both large scale and small scale seismic surveys (Stone 2015).

Bottlenose dolphins

A meta-analysis of marine mammal sightings and seismic surveys across the UK recently reported differences in proximity of animals to operational and inactive airguns. On average, bottlenose dolphins were found 1.5 km closer to inactive airguns when compared with those that were firing. In addition to evidence of disturbance, changes in behaviour were also observed. Faster swimming speeds were observed for bottlenose dolphins during the firing of 'large-arrays', and individuals were more likely to breach or jump (Stone 2015).

Grey seals

Grey seals were also included in the large-scale analysis of the impacts of seismic surveys on marine mammals, and detection rates were significantly lower during activity by 'large-arrays' (Stone 2015).

Common/ Risso's dolphins

In general, there is contrasting evidence for the response of common dolphins to seismic surveys. While some research indicates no change in the occurrence or sighing density of common dolphins when exposed to seismic activity (Stone et al. 2017, Kavanagh et al. 2019), faster swimming speeds have been recorded for this species during the firing of large scale seismic surveys (Stone 2015). In addition, Goold (1996) found a reduction in common dolphin presence within 1 km of ongoing seismic surveys near Pembrokeshire.

Minke whales

While there is little evidence of the impacts of seismic surveys specifically for minke whales, a recent analysis of seismic surveys across the Atlantic found geophysical surveys to be associated with an 88% decrease in the sightings of baleen whales (Kavanagh et al. 2019). Equally, activity of 'large-scale' seismic arrays resulted in a significant decrease in the detection of minke whales in UK waters (Stone et al. 2017). In addition, it was found that a soft-start to seismic surveys also resulted in significantly lower detections when compared with time periods the airguns were shut down.

Thresholds advised and/or used in EIAs

EIAs currently use a range of thresholds to describe the disturbance of marine mammals by seismic activity, including dose response functions, fixed distances and sound pressure levels:

- Dose response for mid frequency sonar, seismic activity and explosions for all cetaceans (Gomez et al. 2016)
- Dose response for geophysical surveys for harbour porpoise and minke whales (Thompson et al., 2013b)
- NMFS threshold guidance for seismic activity (2.6km) (NMFS, 2018)
- Natural England threshold guidance for seismic activity (10km) (Natural England, 2017)
- The fixed disturbance threshold for harbour porpoise advised by JNCC, Natural England & DAERA guidance (10km) (JNCC et al. 2020)
- Seismic survey threshold guidance for LF and MF cetaceans (SPL 160 dB re 1 µPa) (NMFS, 2018)
- Guidance for impulsive noise sources for LF Cetaceans (SPL 120 dB re 1 µPa Southall et al. 2007)
- Guidance for impulsive noise sources for MF Cetaceans (SPL 140 dB re 1 µPa Southall et al. 2007)
- Guidance for impulsive noise sources for all marine mammals (171 dB re 1µPa^{2}s SEL) (based on Southall et al. 2007).

UXO

Description of sound

Clearance of Unexploded Ordnance through detonation is considered to be one of the loudest sources of underwater noise, and as an impulsive sound, it has the potential to cause PTS, TTS and disturbance in marine mammals. The size of the charge weight will impact the sound levels produced by a detonation, which depends on the energy required for the controlled explosion. Depending on the detonation, SELs can be above 223.5 dB re 1 µPa^{2}s at the source. The sound produced by these controlled explosions is low frequency with the main energy centred around 1 kHz (von Benda-Beckmann et al. 2015).

Evidence base for behavioural impact

There are few studies that demonstrate the impacts of UXO clearance on the behaviour of marine mammals. Modelling of the impacts of UXO detonation charges up to 700kg in the Moray Firth suggests that behavioural responses may occur up to 1.5 km and 4.4 km from the source for bottlenose dolphins and minke whales respectively (Marine Scotland 2018). While behavioural disturbance from UXOs has not been described for grey seals, an 800 kg detonation charge may cause PTS in grey seals up to 2.7 km from the source, implying that individuals may be disturbed at even greater distances (BEIS 2020).

Thresholds advised and/or used in EIAs

Evidence of the potential impacts of UXO detonation on marine mammals is mainly described by comparing noise propagation models with impact thresholds for different species groups. For example, it was predicted that a UXO detonation could induce temporary threshold shift in harbour porpoise from 5 - 22.5 km, using SPL peak unweighted thresholds of 196 dB re 1 µPa, and depending on the detonation charge. In contrast, using TTS SEL Weighted 140 dB re 1 $\mu Pa^2 s$ Impulsive criteria, TTS could be induced between 1.7 – 3.9 km for harbour porpoise (HaskoningDHV 2019). It could be assumed therefore that if TTS can occur at these ranges, harbour porpoise could be disturbed at even greater distances (Marine Scotland 2018). A list of currently implemented thresholds for UXO detonation within EIAs includes:

- Low level disturbance thresholds for impulsive noise for cetaceans (Fixed SPL 140 dB re 1 µPa) (NMFS 2005)
- Level B harassment for impulsive noise (Fixed SPL 160 dB re 1 µPa) (NMFS 2005)
- Predicted TTS onset sound levels for seals ($L_{p,pk}$ 212 dB re 1 µPa) (Southall et al., 2007)
- LF Cetaceans likely avoidance (152 dB re 1 µPa RMS, unweighted SELs) (Southall et al. 2007)
- LF Cetaceans possible avoidance (142 dB re 1 µPa RMS, unweighted SELs) (Southall et al. 2007)
- MF Cetaceans likely avoidance (170 dB re 1 µPa RMS, unweighted SELs) (Southall et al. 2007)
- MF Cetaceans possible avoidance (160 dB re 1 µPa RMS, unweighted SELs) (Southall et al. 2007)
- The fixed disturbance threshold for harbour porpoise advised by JNCC, Natural England & DAERA guidance (26 km) (JNCC et al. 2020)

Impact pile driving

Description of sound

Impact pile driving involves driving a steel foundation into the seabed using a large hydraulic hammer to repeatedly hit the foundation. Impact pile driving is a multiple-pulse impulsive sound source, often with very high source levels. For example, recordings have shown source levels up to 250 dB re 1 µPa @ 1m (peak-peak) can be produced every 1–2 seconds and can be detected up to 70 km from the sound source (Bailey et al. 2010). This noise source has been shown to cause both auditory injury (permanent and recoverable, PTS and TTS) as well as behavioural disturbance in marine mammal species.

Evidence base for behavioural impact

Harbour porpoise

Previous studies have shown that harbour porpoises are displaced from the vicinity of piling events. For example, studies at wind farms in the German North Sea have recorded large declines in porpoise detections close to the piling (>90% decline at noise levels above 170 dB) with decreasing effect with increasing distance from the pile (25% decline at noise levels between 145 and 150 dB SEL) (Brandt et al. 2016). The detection rates revealed that porpoise were only displaced from the piling area in the short term (1 to 3 days) (Brandt et al. 2011, Dähne et al. 2013, Brandt et al. 2016, Brandt et al. 2018). Monitoring of harbour porpoise activity at the Beatrice Offshore Wind Farm during pile driving activity has indicated that porpoises were displaced from the immediate vicinity of the pile driving activity – with a 50% probability of response occurring at approximately 7 km (Graham et al. 2019). This monitoring also indicated that the response diminished over the construction period, so that eight months into the construction phase, the range at which there was a 50% probability of response was only 1.3 km. In addition, the study indicated that porpoise activity recovered between pile driving events.

Bottlenose dolphins

In a study on bottlenose dolphins in the Moray Firth (in relation to the construction of the Nigg Energy Park in the Cromarty Firth), small effects of pile driving on dolphin presence have been observed, but dolphins were not excluded from the vicinity of the piling activities (Graham et al. 2017b). In this study the median peak-to-peak source levels recorded during impact piling were estimated to be 240 dB re 1µPa (range 8 dB) with a single pulse sound exposure level at source of 198 dB re 1 $\mu Pa^2 s$. The pile driving resulted in a slight reduction of the presence, detection positive hours and the encounter duration for dolphins within the Cromarty Firth; however, this response was only significant for the encounter durations. Encounter durations decreased within the Cromarty Firth (though only by a few minutes) and increased outside of the Cromarty Firth on days of piling activity. These data highlight a small spatial and temporal scale disturbance to bottlenose dolphins as a result of impact piling activities.

Harbour seals

A study of tagged harbour seals in the Wash has shown that they are displaced from the vicinity of piles during pile-driving activities. Russell et al. (2016) showed that seal abundance was significantly reduced within an area with a radius of 25 km from a pile, during piling activities, with a 19 to 83% decline in abundance during pile-driving compared to during breaks in piling. The duration of the displacement was only in the short-term as seals returned to non-piling distributions within two hours after the end of a pile-driving event.

Grey seals

There are still limited data on grey seal behavioural responses to pile driving. The key dataset on this topic is presented in Aarts et al. (2018) where 20 grey seals were tagged in the Wadden Sea to record their responses to pile driving at two offshore wind farms: Luchterduinen in 2014 and Gemini in 2015. The grey seals showed varying responses to the pile driving, including no response, altered surfacing and diving behaviour, and changes in swimming direction. The most common reaction was a decline in descent speed and a reduction in bottom time, which suggests a change in behaviour from foraging to horizontal movement. The distances at which seals responded varied significantly; in one instance a grey seal showed responses at 45 km from the pile location, while other grey seals showed no response when within 12 km. Differences in responses could be attributed to differences in hearing sensitivity between individuals, differences in sound transmission with environmental conditions or the behaviour and motivation for the seal to be in the area. The telemetry data also showed that seals returned to the pile driving area after pile driving ceased.

Thresholds advised and/or used in EIAs

For impact pile driving, (JNCC 2020b) have advised effective deterrence ranges for harbour porpoise:

- Monopile: 26 km
- Monopile with noise abatement: 15 km
- Pin-pile with and without noise abatement: 15 km

Over the years, several different fixed noise thresholds have been used in EIAs for pile driving:

- Level B harassment (NMFS 2005)
- Low level disturbance (NMFS 2005)
- TTS-onset as a proxy for disturbance (Southall et al. 2007, NMFS 2016, 2018, Southall et al. 2019)
- 75 and 90 dB_{ht}(species) mild and strong avoidance (Nedwell et al. 2007)
- Likely and possible avoidance levels (derived from Southall et al 2007)
- Proposed behavioural response levels (Southall et al. 2007)
- Harbour porpoise behavioural response (Lucke et al. 2009)

For impact pile driving, harbour porpoise and harbour seal dose-response curves have been created and used in offshore windfarm impact assessments:

- Thompson et al. (2013b): Porpoise D/R curve piling noise
- Neart na Gaoithe (2018): Porpoise D/R curve piling noise
- Graham et al. (2017a): Porpoise D/R curve piling noise
- Graham et al. (2019): Porpoise D/R curve piling noise
- Russel and Hastie (2017): Harbour seal D/R curve piling noise
- Whyte et al. (2020): Harbour seal D/R curve piling noise

Wave & Tidal devices

A comprehensive review of the disturbance evidence base and the thresholds used in UK EIAs for wave and tidal devices has been provided in MBIEG (2020). This section provides a high level summary of the findings of that review, but does not intend to duplicate the detail.

The aforementioned report summarises evidence of disturbance of marine mammals by wave and tidal technology and highlights the variability of behavioural responses between and within species. The information in MBIEG (2020) highlights the different behavioural thresholds for disturbance by wave/tidal devices that are currently being implemented. Prior to this report, there was no guidance on thresholds of disturbance by tidal/wave devices; identifying the most commonly implemented thresholds may provide future guidance for the potential impacts of renewable energy in the marine environment. Furthermore, the review identifies a framework that may be used during impact assessments and predictions of displacement by tidal and wave devices.

Description of sound

Sound recorded around wave & tidal devices is rather low frequency, tonal, and with harmonics up to 2 kHz (Risch et al. 2020).

Evidence for behavioural impact

In general, there is limited evidence of displacement of marine mammals by single tidal devices. The operation of the SeaGen tidal turbine in the Strangford Narrows in Northern Ireland has been associated with a redistribution of individuals, with less harbour seals found in proximity to the device. Visual monitoring observed decreases in seals up to 400m of the installation, and telemetry studies demonstrated localised turbine avoidance up to 250m either side of the turbine (Sparling et al. 2017a). While a reduction in seal movements was detected when the turbine was active, local haulouts were still occupied, and movement still occurred within and around the Strangford Lough SAC. In comparison, the deployment of PAM devices in proximity to the DeltaStream turbine in Ramsay Sound did detect a dolphin within 5m of the stationary device, and a porpoise 15m from the active turbine. However, due to the limited detection range of the monitoring devices, and a short duration of overlap between PAM and operational turbines, no further analysis of disturbance could occur Malinka et al. (2018).

Evidence of disturbance by tidal and wave technology has been observed more frequently at sites with multiple devices. The MeyGen tidal site is comprised of four 1.5 MW tidal turbines, and Passive Acoustic Monitoring revealed that during flood tide, operational turbines were associated with a 78% reduction in harbour porpoise presence (95% CI: 51%-91%) (Palmer et al., in review). In addition, an increase in the number of active turbines was linked to further harbour porpoise reductions. However, approximately 30% of porpoise and dolphin detections occurred during times when the turbines were active, indicating towards continued, if reduced occupation of the surrounding habitat. Further research into the impacts at MeyGen included the tagging of 54 harbour seals in the nearby area. While overall at sea distributions of seals were not significantly influenced by the presence of turbines, operation resulted in a significant decline of seal presence up to 2km from the array (Onoufriou 2020). However, patterns of disturbance are not uniform across deployment sites, with some marine energy sites suggesting disturbance at a smaller geographic range. Disturbance at the tidal turbine demonstration area in the Bay of Fundy was analysed over an eight-year period using PAM. Porpoise were detected during the installation and operation of the 2 MW OpenHydro tidal turbine, and there was a significant decrease in porpoise vocalisations during operation. This effect was strongest up to 300m from the device and was significant up to 1 km from the device (Tollit et al. 2019).

Where evaluating the impacts of tidal turbine noise is not feasible, some studies have attempted to determine potential disturbance thresholds using playback. Along the west coast of Scotland, playback of sound from the SeaGen turbine was emitted, while GPS tags and land-based visual surveys were used to evaluate the impact on harbour seals.

The number of seals recorded in the channel did not change significantly; however, reduced usage was observed in the playback area by tagged seals, an effect that continued up to 500 m from the sound source (Hastie et al. 2017). Conversely, similar playback studies conducted in Canada in Admiralty Inlet found no effect of turbine noise on harbour seals, which could be due to differences in the noise propagation and the associated received levels (Robertson et al. 2018). In contrast, avoidance of playback was observed by harbour porpoise in the same area. However, the implementation of multiple trials suggested that habituation may have occurred, as avoidance of harbour porpoise decreased from ~ 300 m in the first trial, to no evidence of avoidance in the final playback experiment.

Overall, disturbance of marine mammals by tidal devices is expected to occur over a relatively small geographic range, with evidence of displacement and behavioural responses up to 2 km from the device locations. It is theorised that observed differences in behavioural response may be linked to the environment surrounding the devices, making thresholds both site and individual specific. The conceptual framework outlined in the disturbance review highlights a progression of questions that may help to evaluate the behavioural response of marine mammals to tidal/wave devices in the future. It was concluded that four main concepts may be addressed to better understand the potential of disturbance: the number of animals that may be impacted, the potential severity of the disturbance, the functional use of the habitat, and the sensitivity of the local population. While it may not be possible to answer all these questions, the review summarises the key principles that can be at least considered and will allow for the identification of clear data gaps within impact assessments in the future.

Thresholds advised and/or used in EIAs

- Level B strong disturbance (SPL 120 dB re 1μPa at 1m) (NMFS 1995, 2005)
- An unweighted median received SPL of 142 dB re 1 μPa derived from Hastie et al 2018 (the median received level identified a significant reduction in harbour seal from operational tidal turbine noise.
- ‘Mild’ and ‘Strong’ behavioural reaction: 75 dBht or 90 dBht above species specific hearing threshold (Nedwell et al. 2005)
- Aversive behavioural reaction in porpoise: $L_{p,pk-pk}$ 168 dB re 1 μPa or 164.3 dB re 1 $\mu Pa^2 s$ SEL (Lucke et al. 2009)
- Low level disturbance: SPL 140 dB re 1 μPa (HESS 1997)

Appendix 3: Overview of the HRA Process and SACs in Welsh Waters

HRA Process

The Habitats Directive (Council Directive 92/43/EEC), together with certain elements of the Wild Birds Directive (Directive 2009/147/EC), were implemented into UK law through a series of Regulations, typically referred to collectively as the **Habitat Regulations**. In Welsh waters, the Conservation of Habitats and Species Regulations 2017 (as amended) covers inshore waters up to 12 nautical miles, with The Conservation of Offshore Marine Habitats and Species Regulations (2017) covering offshore waters. The Habitats Directive includes a number of species within Annex II, for which a network of Special Areas of Conservation (SACs) are required to be established. With respect to marine mammals, that includes harbour seal, grey seal, harbour porpoise and bottlenose dolphin.

Following Brexit, the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations (2019) apply. The change means (among other matters) that existing Special Areas of Conservation (SACs) remain but are no longer part of the Natura 2000 network and instead form part of the National Site Network. Maintaining a coherent network of protected sites with overarching conservation objectives is still required, with the network objectives being:

- Maintain or, where appropriate, restore habitats and species listed in Annexes I and II of the Habitats Directive to a FCS);); and
- Contribute to ensuring, in their area of distribution, the survival and reproduction of wild birds and securing compliance with the overarching aims of the Wild Birds Directive.

For the purpose of the current document, it is therefore assumed that all existing conservation objective for relevant sites still apply, with the overarching aim being FCS.

The **Habitat Regulation Assessment** (HRA) process includes several stages, which are provided for in the Habitat Regulations. Broadly, for a plan or project (not necessary to the management of a site), there is a requirement to determine if that plan or project may affect the designated feature(s) (i.e. the habitats and species for which a site is designated) of a relevant site prior to consent being granted. That assessment is carried out with respect to the integrity of the site(s) in question and in the context of the conservation objectives and condition of the feature(s). HRA is therefore different to EIA – although the species and effect are the same, HRA is focused at site level and whether the effect would be significant or adverse on that site. The relevant conservation objectives and conservation status of the feature are therefore integral to the HRA process. This section of the report reviews documents relevant to the HRA process, to identify how disturbance related to underwater noise is assessed for marine mammals and how such approaches may apply to relevant SACs in Welsh waters.

Marine Mammal SACs in Welsh Waters

Cardigan Bay/ Bae Ceredigion SAC

Cardigan Bay/Bae Ceredigion SAC is designated for grey seal and bottlenose dolphin (amongst other, non-marine mammal, features). Cardigan Bay, extending from Lleyn Peninsula to St. David's Head, is one of the largest bays in the British Isles. Originally designated for the regularly occurring bottlenose dolphin population, it is also designated for grey seal.

Bottlenose dolphins are seen year-round in Cardigan Bay, with increases in abundances and group sizes through the summer months, peaking in September and October. Calving is known to occur within the bay, with new-born calves recorded between April – September; birthing areas appear to be shallower, more sheltered areas. The residency of individuals is highly variable, with some having a small local range and others being more wide ranging, with many individuals (30%) also recorded within the Pen Llyn a'r Sarnau/ Lleyn Peninsula and the Sarnau SAC and elsewhere around the Welsh coast. The current population of bottlenose dolphin is stated as 147 individuals and the species are considered to be in favourable conservation status as a feature of the SAC.

Grey seals within the SAC are part of the South West England and Wales management unit, with no specific population defined within the SAC. Pupping is focused within the south-west of the site, with the pup production within the SAC a small contribution to the south west Wales population. Where pupping occurs, secluded coves and caves are used, rather than the large gatherings in open areas as seen elsewhere around the UK. The conservation status of grey seal within the SAC is assessed as favourable.

The conservation objectives for the SAC, as relevant to bottlenose dolphin and grey seal, are as follows:

- **CO1: The population is maintaining itself on a long-term basis as a viable component of its natural habitat**
- **CO2: The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future**
- **CO3: The presence, abundance, condition and diversity of habitats and species required to support this species is such that the distribution, abundance and populations dynamics of the species within the site and population beyond the site is stable or increasing.**

Specific advice and guidance relating to the Conservation Objectives and what should be achieved to consider the success of the conservation objective and the FCS of the species is provided within the Regulation 37 advice for the SAC. However, it should be noted that as part of the above conservation objectives the following components are of importance:

CO1:

- As part of this objective it should be noted that for bottlenose dolphin and grey seal;
    - Contaminant burdens derived from human activity are below levels that may cause physiological damage, or immune or reproductive suppression

- For grey seal, populations should not be reduced as a consequence of human activity.

CO2:

- As part of this objective it should be noted that for bottlenose dolphin and grey seal:
    - Their range within the SAC and adjacent inter-connected areas is not constrained or hindered
    - There are appropriate and sufficient food resources within the SAC and beyond
    - The sites and amount of supporting habitat used by these species are accessible and their extent and quality is stable or increasing

Conservation objective 2 is therefore directly relevant to underwater noise disturbance.

Pen Llyn a`r Sarnau/ Lleyn Peninsula and the Sarnau SAC

Pen Llyn a`r Sarnau/ Lleyn Peninsula and the Sarnau SAC is designated for bottlenose dolphin and grey seal (amongst other, non-marine mammal, features). It is located at the north of Cardigan Bay and encompasses the Lleyn Peninsula.

Bottlenose dolphin are a transient species within this SAC, not showing the same semi-resident tendency as seen within the Cardigan Bay SAC. The population abundance and conservation status for this species within this SAC has been based on that for the Cardigan Bay SAC due to the connectivity between the sites. The current population of bottlenose dolphin is stated as 147 individuals and the species are considered to be in favourable conservation status as a feature of the SAC.

Grey seals within the SAC are part of the South West England and Wales management unit, with no specific population defined within the SAC. The breeding colonies at Pen Llyn and Bardsey Island are the larger sites within north Wales, with a number of important sites located in the north of the SAC. As with the Cardigan Bay SAC population, a high proportion of grey seals within the Lleyn Peninsula SAC use rocky coves and caves for pupping rather than more open sites. The conservation status of grey seal within the SAC is assessed as favourable.

The conservation objectives for the SAC, as relevant to bottlenose dolphin and grey seal are as follows:

- **CO1: The population is maintaining itself on a long-term basis as a viable component of its natural habitat**
- **CO2: The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future**
- **CO3: The presence, abundance, condition and diversity of habitats and species required to support this species is such that the distribution, abundance and populations dynamics of the species within the site and population beyond the site is stable or increasing.**

Specific advice and guidance relating to the Conservation Objectives and what should be achieved to consider the success of the conservation objective and the FCS of the species is provided within the Regulation 37 advice for the SAC. However, it should be noted that are part of the above conservation objectives the following components are of importance:

CO1:

- As part of this objective it should be noted that for bottlenose dolphin and grey seal;
  - Contaminant burdens derived from human activity are below levels that may cause physiological damage, or immune or reproductive suppression
- For grey seal populations should not be reduced as a consequence of human activity.

Conservation objective 2 is therefore directly relevant to underwater noise disturbance.

Pembrokeshire Marine/ Sir Benfro Forol SAC

Pembrokeshire Marine/ Sir Benfro Forol SAC is designated for grey seal (amongst other, non-marine mammal, features). It covers most of the Pembrokeshire coast, from near Abereiddy in the north to Manorbier in the south, including the coastline and seas around the islands off Pembrokeshire: Ramsey, Skomer, Grassholm, Skokholm, the Bishops and Clerks, and The Smalls.

The site documents note that grey seals within the SAC are part of the South West England and Wales management unit (noting that the grey seal management unit is currently being reviewed, see Figure 14), with no specific population defined within the SAC. The Pembrokeshire coast is the most important site for pupping grey seals in Wales. As elsewhere along the west Wales coastline, the pupping occurs in secluded coves and caves rather than open sites with high numbers of individuals. The conservation status of grey seal within the site is assessed as favourable.

The conservation objectives for the SAC, as relevant to grey seal are as follows:

- **CO1: The population is maintaining itself on a long-term basis as a viable component of its natural habitat**
- **CO2: The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future**
- **CO3: The presence, abundance, condition and diversity of habitats and species required to support this species is such that the distribution, abundance and populations dynamics of the species within the site and population beyond the site is stable or increasing.**

Specific advice and guidance relating to the Conservation Objectives and what should be achieved to consider the success of the conservation objective and the FCS of the species is provided within the Regulation 37 advice for the SAC. However, it should be noted that are part of the above conservation objectives the following components are of importance:

CO1:

- As part of this objective it should be noted that for bottlenose dolphin and grey seal;

        - Contaminant burdens derived from human activity are below levels that may cause physiological damage, or immune or reproductive suppression
- For grey seal, populations should not be reduced as a consequence of human activity.

CO2:

- As part of this objective it should be noted that for bottlenose dolphin and grey seal:
    - Their range within the SAC and adjacent inter-connected areas is not constrained or hindered
    - There are appropriate and sufficient food resources within the SAC and beyond
    - The sites and amount of supporting habitat used by these species are accessible and their extent and quality is stable or increasing

Conservation objective 2 is therefore directly relevant to underwater noise disturbance.

Bristol Channel Approaches / Dynesfeydd Môr Hafren SAC

The Bristol Channel Approaches/Dynesfeydd Môr Hafren SAC is located in the Bristol Channel, and stretches between the north Cornwall coast to Carmarthen Bay in south Wales. It is solely designated for harbour porpoise.

The SAC was designated due to a consistently high density of harbour porpoise, with a particular importance during the winter months (considered to be October – March (inclusive)). Harbour porpoise are a wide ranging, highly mobile, species and the distribution of the species is considered to be primarily driven by prey abundance and distribution. The harbour porpoises within this SAC are a part of the Celtic and Irish Seas Management Unit, with the SAC supporting at least 4.7% of the MU population. The conservation status of harbour porpoise in the UK is currently assessed as unknown.

The conservation objectives for the site are:

- **CO1: Harbour porpoise is a viable component of the site**
- **CO2: There is no significant disturbance of the species**
- **CO3: The condition of supporting habitats and processes, and the availability of prey is maintained.**

Conservation objective 2 is therefore directly relevant to underwater noise disturbance.

North Anglesey Marine / Gogledd Môn Forol SAC

The North Anglesey Marine/Gogledd Môn Forol SAC extends from the north and west coast of Anglesey into the Irish Sea. It is solely designated for harbour porpoise.

The SAC is designated due to the year-round presence of a high number of harbour porpoise, with the site considered to support approximately 2.4% of the Celtic and Irish Seas MU population.

The conservation objectives for the SAC are identical to those for the Bristol Channel Approaches/Dynesfeydd Môr Hafren SAC and so have not been repeated here.

West Wales Marine / Gorllewin Cymru Forol SAC

The West Wales Marine / Gorllewin Cymru Forol SAC covers much of Cardigan Bay, stretching from the Lleyn Peninsula in the north to Pembrokeshire in the south. The site overlaps with a number of other SACs, including part of the Pen Llyn a`r Sarnau/ Lleyn Peninsula and the Sarnau SAC and encompassing the Cardigan Bay/ Bae Ceredigion SAC. It is solely designated for harbour porpoise.

The site is designated for being considered important habitat for harbour porpoise during the summer months (April – September inclusive), with part of the site within Cardigan Bay being considered of particular importance during the winter. The site is thought to support 5.4% of the Celtic and Irish Seas MU population.

The conservation objectives for the SAC are identical to those for the Bristol Channel Approaches/Dynesfeydd Môr Hafren SAC and the North Anglesey Marine/Gogledd Môn Forol SAC and so have not been repeated here.

Appendix 4: HRA Guidance

Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs

A guidance document was published in June 2020 by JNCC, DAERA and Natural England, with a note that Scottish Natural Heritage (SNH) (now NatureScot) and NRW will provide separate advice for sites which are their joint responsibility with JNCC and Natural England. There are a number of harbour porpoise SACs that fall partly or wholly in Welsh waters, as follows:

- Bristol Channel Approaches / Dynesfeydd Môr Hafren SAC;
- North Anglesey Marine / Gogledd Môn Forol SAC; and
- West Wales Marine / Gorllewin Cymru Forol SAC.

Detail on these sites is provided Appendix 3: Overview of the HRA Process and SACs in Welsh Waters: Marine Mammal SACs in Welsh Waters, with the relevant conservation objective for all being 'there is no significant disturbance of the species'. The JNCC (2020b) guidance provides advice on how to assess and manage risk of significant disturbance with respect to noise. A number of activities are identified as being potentially significant, as follows:

- Geophysical survey;
- Seismic surveys for oil and gas exploration;
- Detonation of unexploded ordnance;
- Acoustic Deterrent Devices (ADDs); and
- Pile driving for installing offshore wind turbines and other marine facilities.

The focus on these activities is a consequence of the licensable nature of the activities but also the peak sound energy in terms of frequency (aiming to focus on activities most likely to disturb harbour porpoise), and to align the guidance with the Marine Noise Registry and the data collected therein.

The document notes that whereas non trivial disturbance in EIA and SEA is assessed at population level within the relevant management unit, **the SAC conservation objective requires significant disturbance to be avoided at site level**. Significant disturbance is defined in the guidance as follows:

Noise disturbance within a SAC from a plan/project, individually or in combination, is considered to be significant if it excludes harbour porpoise 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.

It is understood that the above definition of significant disturbance applies to harbour porpoise SACs in Welsh waters and is tied to the conservation objective concerned with significant disturbance. The evidence base for the definition is provided within the guidance document and is not repeated here. The focus of the following is therefore on the approach recommended within the guidance for determining the contribution of an individual activity to that value of significant disturbance, commonly referred to as the EDR approach.

For some developments, their Reports to Inform Appropriate Assessment (or shadow HRA's) have applied EDRs as screening ranges where sites (SACs), plans or projects at greater distances than the EDR are screened out of appropriate assessment. EDR's were not designed for this purpose, however, and should be reserved for analysis during the Appropriate Assessment to quantify whether an Adverse Effect on Site Integrity has occured.

The primary use of the EDR is for assessment purposes during the Appropriate Assessment stage of HRA. The application of an EDR is a habitat based approach and not a species based approach; the definition of significant disturbance is the driver, as it relates to habitat loss and not disturbance of an individual(s). The EDR effectively refers to potential for a temporary habitat loss as a consequence of a displacement/disturbance response to underwater noise. The EDRs are informed by empirical evidence where available, that focused on a reduction in porpoise vocal activity or sightings, but crucially should not be considered either 100% displacement within that range or the maximum range of such effect. Further, it is clear that the evidence base is small and variable in terms of reporting, with the consequences of such temporary habitat loss for individuals not recorded (the conservation objective concerned with harbour porpoise as a viable component of the site is more appropriate there). The EDR recommended for each activity is based on either a recommendation in the literature, an average or in some cases maximum of the available values or a precautionary assumption based on the available data.

Table 10 below summarises the EDRs identified in the guidance, including a summary of how the range was determined and the references available. It should be noted that for assessment purposes, the EDR is applied as an area, derived by the central point being located on the source of the sound and the radius being equivalent to the EDR. The area within that circle that overlaps with the SAC (noting not all of the circle may do so), alone and in-combination, is used to calculate the percentage of the SAC (or seasonal extents) affected and if that percentage is within the % thresholds identified above.

Table 10 JNCC (2020): Recommended effective deterrence ranges (EDR)

Activity	**EDR (km)**	**Background to range**	**References in which EDRs were based**
Monopile	26	A range of deterrent ranges reported (18-34 km), with variable return times (few hours-~3 days), with 26 km deemed an overall range (i.e. not all harbour porpoise inside that range would be displaced and some outside may be displaced, with 26 km viewed as a balance between the two).	Tougaard et al. (2009) Dähne et al. (2013) Brandt et al. (2011), Brandt et al. (2012), Brandt et al. (2018)

Activity	EDR (km)	Background to range	References in which EDRs were based
Monopile with noise abatement	15	Studies found a range for deterrent (12-17 km), with 15 km being an average of the ranges published.	Dähne et al. (2017) Rose et al. (2019) Dähne et al. (2017), Brandt et al. (2018)
Pin-pile (with and without noise abatement)	15	The single study recorded deterrent after 12 hours, with 50% probability of behavioural response at 7.4 km and 25% at 18 km. Habituation was noted, with response distance falling over time. 15 km was recommended to ensure the bulk of the effects while piling was ongoing were included.	Graham et al. (2019)
Conductor piling for oil & gas wells	15	Small diameter piles (<1 m) with lower noise amplitude than OWF monopiles. The 15 km pin pile EDR is therefore recommended.	Jiang et al. (2015); MacGillivray (2018); Jiang et al. (2015), Graham et al. (2019)
UXO	26	No empirical evidence is available for deterrent response to UXO clearance. A one off detonation would likely elicit a startle response only, but a longer campaign with multiple detonations, vessels and ADDs would be expected to be different.	Based on monopile EDR
Seismic (airguns only) survey	12	A reduction in acoustic activity at variable ranges were noted for air gun survey (8, 10 and 12 km).	Thompson et al. (2013a); Sarnocinska et al. (2019)
Some types of geophysical surveys (sub bottom profilers and multi-beam echo sounders only)	5	No field observations of responses are available, with the range a conservative value based on noise measurements and modelling	Crocker and Fratantonio (2016); Crocker and Fratantonio (2016), Crocker et al. (2019)

It is therefore clear that the EDR approach enables the potential consequences for the relevant conservation objective to be determined (in terms of potential for a temporary reduction in undisturbed habitat as a defined percentage of the site for the timeframes required). It is also clear, however, that should additional evidence be available, that a variation in the EDR applied and/or the duration of that EDR could be justified. Specifically, the guidance is clear that:

'Different EDRs and estimates of the duration of impact may be justified if there is evidence relating to sound levels and propagation, harbour porpoise response, recovery and habituation. Ideally, the choice of EDR should be based on field observations and measurements'.

NRW's position on the Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs. (England & Northern Ireland) (unpublished)

NRWs position on JNCC et al (2020b) clarifies that NRW agrees with the application of the 10%/20% thresholds when determining if disturbance from noise would be significant (ie if an adverse effect on integrity would result) – this is an integral part of the Conservation Objectives. As regards the EDR approach for determining the contribution of a plan or project to those thresholds, NRW highlight that considerable uncertainty is evident in the evidence underpinning the calculations, especially in Welsh waters. Additional data on underwater noise propagation and behavioural responses of marine mammals are required for Welsh waters, and recommends that measures should be taken to address these gaps either strategically or on a project by project basis.

The paper also highlights that given the scale of the SACs in Welsh waters, a single 26km EDR that was fully within the West Wales Marine SAC would exceed the 20% threshold on a daily basis; it is less clear what the implications could be for the 10% threshold (which is averaged across a season and would therefore require an estimate of the number of occurrences within that season). The highlighted risk of derogation, in the absence of suitable mitigation, is an important point for a developer to consider.

Conservation and Management Advice: Inner Hebrides and the Minches SAC (NatureScot 2020)

The guidance provides advice on activities that may affect the protected feature of the SAC (harbour porpoise only) and hence provides a Scottish perspective on assessing impacts on harbour porpoise in SACs. The main purpose of the SAC is to '*contribute to the favourable conservation status of harbour porpoise in the Atlantic Biogeographic Region*'. The SAC sits within the West Scotland Harbour Porpoise Management Unit (and supports approximately 32% of the harbour porpoise occurring within that unit), and forms part of the wider Marine Atlantic Biogeographic Region, as depicted in Figure 21 below.

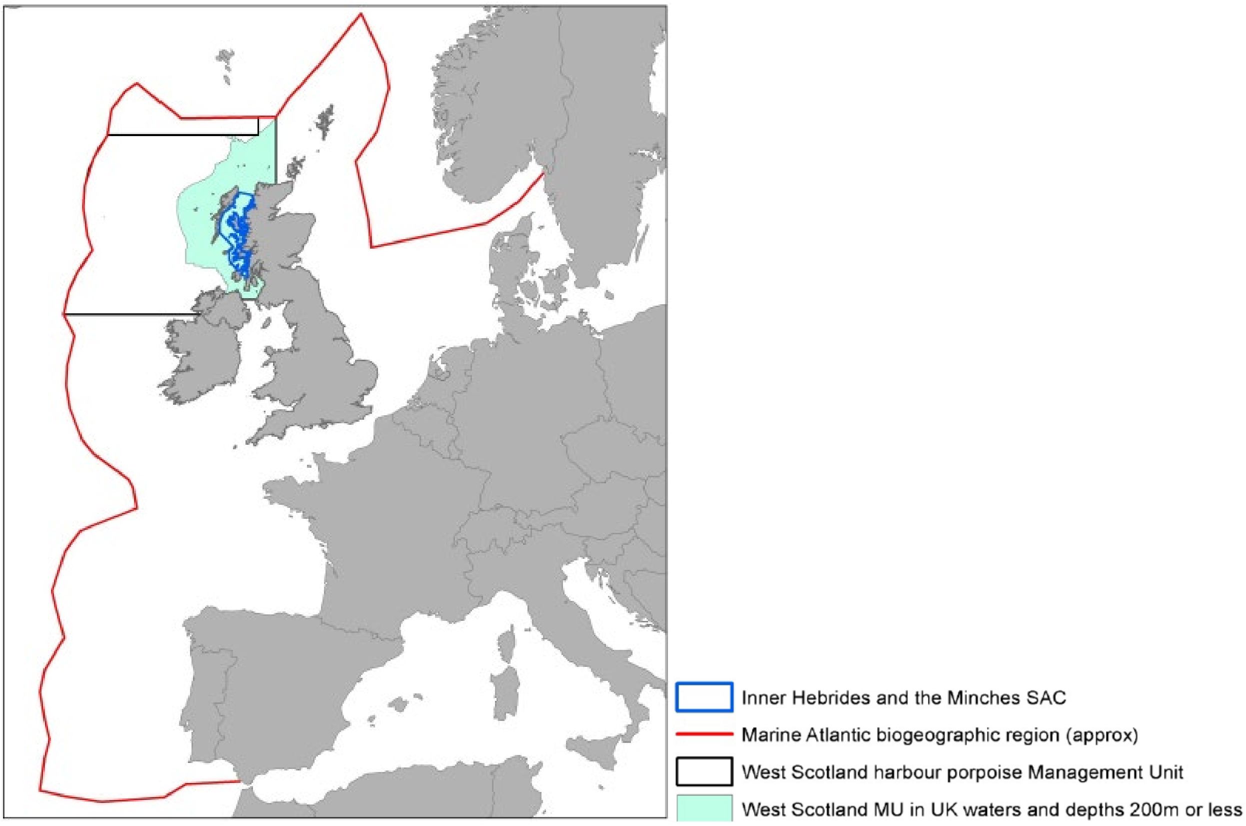

Figure 21: Location of the Inner Hebrides and the Minches SAC in the West Scotland management unit in UK waters (in depths of 200 m or less, the depth utilised by the species) and the Atlantic Biogeographic Region (NatureScot 2020)

At the time of designation, the feature was considered to be in favourable condition with the aim of the conservation objectives being to maintain that. It should be noted that the UK harbour porpoise conservation status was updated by JNCC in 2019, and while range and future prospects for the species across the UK were deemed favourable it was considered insufficient information was available on population trends and therefore the overall conclusion on conservation status was unknown. The conservation objectives for the site are:

1. To ensure that the Inner Hebrides and the Minches SAC continues to make an appropriate contribution to harbour porpoise remaining at favourable conservation status.

2. To ensure for harbour porpoise within the context of environmental changes, that the integrity of the Inner Hebrides and the Minches SAC is maintained through 2a, 2b and 2c:

2a. Harbour porpoise within the Inner Hebrides and the Minches are not at significant risk from injury or killing.

2b. The distribution of harbour porpoise throughout the site is maintained by avoiding significant disturbance.

2c. The condition of supporting habitats and the availability of prey for harbour porpoise are maintained.

Provided site integrity is maintained under Conservation Objective 2, then the guidance deems the SAC to be maintaining its contribution to FCS.

Conservation Objective 2b is the focus for disturbance, with the aim of the objective being to ensure that harbour porpoise can continue to use and have access to all areas of the site by avoiding significant disturbance. Harbour porpoise are present within the site throughout the year, with May to August being particularly important for breeding and calving. The term significant disturbance as applied in the report '*should be interpreted to mean disturbance that affects the integrity of the site through alteration of the distribution of harbour porpoise within the SAC such that recovery cannot be expected or effects can be considered long term*'. Effects lasting beyond the average generation time of harbour porpoise are considered more likely to result in a significant disturbance (defined as impacts lasting 8 years or more).

Factors that may limit recovery include timing and duration of disturbance and the ability of individuals to access sufficient food while being disturbed.

The protection of marine European Protected Species from injury and disturbance

The draft guidance was published by JNCC with CCW and NE in June 2010. European Protected Species (EPS) are provided for under the Habitats Regulations and includes all species of cetacean. The requirement is not site based (and is therefore not aimed at delivering on conservation objectives), but for disturbance is instead concerned with determining whether the disturbance would be significant enough to increase the risk of a negative impact to a population of an EPS at Favourable Conservation Status (FCS). There is, therefore, potential cross over with HRA.

The guidance defines disturbance of animals as any disturbance likely to:

- impair their ability:

(i) survive, to breed or reproduce, or to rear or nurture their young; or

(ii) in the case of animals of a hibernating or migratory species, to hibernate or migrate; or

- affect significantly the local distribution or abundance of the species to which they belong.

Such significant disturbance is considered more likely to occur when there is a risk of:

- Animals incurring sustained or chronic disruption of behaviour scoring 5 or more in the Southall et al. (2007) 'behavioural response severity scale'; or
- Animals being displaced from the area, with redistribution significantly different from natural variation.

The specifics of which activities may result in significant disturbance or how to determine significance are not given, due to variability between activity, species and location. However, the parameters that determine when the FCS of a species can be taken as favourable are given, as it is against these that potential for a given disturbance to be defined as significant or not is assessed:

- Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable element of its natural habitats;
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; and
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Of the above bullet points, the second and third are relevant to disturbance, displacement and potential redistribution (the term viable relates more to population size and structure).

The protection of Marine European Protected Species from injury and disturbance (Marine Scotland, 2020)

The guidance is focused on cetaceans occurring in Scottish waters. The document acknowledges the relevant legislation in relation to injury and disturbance, with the purpose to provide a licensing route for activities at risk of causing an offence. Such activities must meet the relevant three tests if they are to be granted a licence – namely that the activity is licensable, there are no alternatives and it will not affect FCS.

The first step in the process is to understand the species occurring, densities, frequency of occurrence etc., followed by defining the impacts and any mitigation measures. **Defining when disturbance would be significant is acknowledged as not clear**, but dependent on the following:

- The spatial and temporal distribution of the animal in relation to the activity;
- The duration of the activity;
- Any behaviour learned from prior experience with the activity;
- Similarity of the activity to biologically important signals (particularly important in relation to activities creating sound); and
- The motivation for the animal to remain within the areas (e.g., food availability).

Activities that may result in disturbance are listed, together with potential consequences of that disturbance (in terms of change in distribution, disruption to communication etc).

The recommended approach is to follow a cetacean Risk Assessment, to enable the risk of an offence occurring to be determined, followed by confirmation of whether the three tests have been met. The risk assessment should take account of the following:

- Duration and frequency of the activity;
- Intensity and frequency of sound and extent of the area where injury/disturbance thresholds could be exceeded, as chronic noise exposure increases the risk of a disturbance offence;
- Combination effects;
- Species specific noise criteria as outlined by Southall et al (2007) (noting that the guidance specifically recommends the injury criteria as well as the noise criteria in general); and
- Mitigation measures.

JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (seismic survey guidelines)

The guidelines were published by the JNCC in 2017, and were aimed at reducing the risk of injury. It is noted in the document that the measures could also reduce the risk of disturbance.

JNCC guidelines for minimising the risk of disturbance and injury to marine mammals whilst using explosives 2010

The guidelines were published by the JNCC in 2010, and were aimed at reducing the risk of injury. It is noted in the document that the measures could also reduce the risk of disturbance.

Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise 2010

The guidelines were published by the JNCC in 2010, and were aimed at reducing the risk of injury. It is noted in the document that the measures could also reduce the risk of disturbance.

Regulation 37 Advice

The UK guidance documents identified above are specific to harbour porpoise designated sites and EPS, the latter relevant to all cetaceans and therefore including bottlenose dolphin. No specific UK guidance on disturbance of seals with respect to the Habitats Regulations have been identified. However, the Habitats Regulations places a requirement on statutory bodies to provide advice on marine sites in relation to the sites conservation objectives and activities that may cause deterioration to them. The most recent such documents are termed Regulation 37 advice, with previous iterations as Regulation 35 or 33.

As an example, the Regulation 37 advice for the Pembrokeshire Marine SAC was drafted in 2018 and includes advice on grey seal. The document reviews activities that may cause deterioration or disturbance to features, requiring appropriate steps to avoid significant disturbance.

For seals, important considerations include the species' range (including prey), population and supporting habitats and species, but also that '*disturbance by human activity is below levels that suppress reproductive success, physiological health or long-term behaviour*'.

Similarly, the Regulation 37 advice for Cardigan Bay SAC, for example, includes bottlenose dolphin and was published in 2018. The document reviews activities that may cause deterioration or disturbance to features, requiring appropriate steps to avoid significant disturbance.

For bottlenose dolphin, important considerations include displacement, sub-lethal physiological effects, modification of behaviour, species population, distribution and range.

As for the grey seal example above, the document also notes that ‘disturbance by human activity is below levels that suppress reproductive success, physiological health or long-term behaviour’.

Concept for the Protection of Harbour Porpoises from Sound Exposures during the Construction of Offshore Wind Farms in the German North Sea (ASCOBANS, 2014)

The report was published by ASCOBANS (2014), as part of a review of new threats to small cetaceans. The purpose behind the document was to provide greater clarity with regard to the requirements for the protection of harbour porpoise from sound exposures during construction of offshore wind farms in the German North Sea (Sound Protection Concept). The document also aims to provide certainty as regards the terms ‘injury’ and ‘significant disturbance’. Harbour porpoise is used as an indicator species.

It is of note that the harbour porpoise of the German North Sea area were considered to be a local population that cannot be divided further, with the period May to August being particularly sensitive due to the importance of the timeframe for reproductive success.

The document discusses PTS and TTS in the context of injury risk, with a SEL of 140 dB re 1µPa²s highlighted for significant behavioural disturbance(Brandt et al. 2011). A flight response and avoidance behaviour were also noted at distances over 20 km (Tougaard et al. 2006, Lucke et al. 2009). Whilst the report highlighted that specific sound pressure levels sufficient to result in a particular disturbance related consequence (e.g. separation of mother from calf) are not known, it is clear that disturbance as a consequence of sound can result in individuals being driven away from an area, with frequency of that sound also being important.

Methods to survey a disturbance response in harbour porpoise are described as methods to detect a change in vocal activity, or a change in the number of animals present. Neither approach enables the consequence of disturbance to be assessed, not surprising given the difficulties and variables involved in attempting to do so.

The Population Consequences of Acoustic Disturbance (PCAD) model is referenced as a measure to analyse population level effects, together with the use of PODs to record vocalisations. However, if the spatial extent of disturbance is to be considered, the report notes that noise propagation characteristics need to be taken into account, particularly across the 20 km range of interest to the report. Consideration was therefore given to a number of studies that present field data collected from PODs during piling activity, referenced to modelled noise levels predicted across the observed extent of disturbance.

It was concluded that an exact threshold for disturbance could not be set, given the variable levels of response reported. However, it was considered that sufficient information existed to establish a mandatory noise threshold of 160 dB re 1 µPa²s (SEL) at a distance of 750 m in order to avoid TTS, with disturbance (in particular avoidance and flight behaviour) consequently limited to a radius of 8 km around the sound source. From back calculation, the report found that at that range (8 km), the sound level would be expected to have reduced to 140 dB re 1µPa²s (SEL).

Three disturbance radii were identified in the report, as provided below in Cardigan Bay/Bae Ceredigion SAC and Pembrokeshire Marine/ Sir Benfro Forol SAC , which form the basis for the interpretation of relevant nature conservation law within the framework of the Sound Protection Concept presented in the report.

Table 11 Disturbance radii dependent on sound exposure

dB SEL at a distance of 750 m	Disturbance Radius (km)
160	8
155	5
150	3

The report is clear that with respect to disturbance, the requirements of the Habitats Directive in Germany do not prohibit all disturbance year round. A significant disturbance would be considered one where the conservation status of the local population worsened. The following criteria are drawn on for that assessment:

- Current natural range (extent, trend);
- Population (population size, reproduction, age structure, mortality, health status);
- Habitat for the species (area and quality, including structures and functions); and
- Future prospects (as regards to population, range and habitat availability, including pressures and threats, and long-term viability).

The document is also clear that '*it is therefore not the disturbance of an individual animal that is relevant under species protection law*'. Rather, it related to the cumulative footprint of multiple piling radii that were of concern at population level, and it is only at population level that it becomes relevant under the legislation. A number of conventions were recommended, in terms of disturbance radius and distance from protected sites, to enable practical implementation as well as the known density of animals to be taken into account. The relevant measures are also seasonal, to account for the sensitive May to August period.

Effectively, to avoid a significant population level effect within the German region (with all harbour porpoise within the region considered a population), sufficient sea space unaffected by piling noise is deemed to be required. A 10% limit on the extent of the German EEZ that could fall within a piling radius at any one time was therefore recommended. That value was derived from Lambrecht et al. (2004) (noting that it has not been possible to source this reference, cited in ASCOBANS 2014), which found that a 1% permanent loss of habitat, with specific reference to Special Protection Areas (SPA and therefore presumed to be derived from a connection to birds) would be termed adverse. In the context of exposure caused by pile driving activities, which occurs for limited periods of time, i.e. it being short term and temporary in nature, it was considered justifiable from a technical, nature conservation perspective for ten times that figure to apply (i.e. the 10% value). In the most sensitive period of May-August, harbour porpoise are most concentrated in one particular area of sea (north west of Sylt), with that area subject to a more stringent threshold of 1% within piling radius for that period of time.

For projects > 8km from a site designated for harbour porpoise and that comply with the noise threshold levels, no HRA requirement applies (although there will remain a need to assess for non HRA matters).

Marine mammals and underwater noise in relation to pile driving – Working Group 2014

Published in 2015 (Energinet.dk 2015a), the document was produced by a working group tasked with investigating how underwater noise from the installation of impact driven foundations at planned offshore wind farms in Denmark could be regulated in order to take due consideration of protected marine species. Specific to disturbance, i.e. noise insufficient to result in TTS or PTS, it was considered that it may affect and alter the behaviour of the animals, with potential implications for the long-term survival, and reproductive success of individual animals. If a sufficiently large number of individuals were affected, this could result in the status of the population being be affected. While the consequences of disturbance can include severe reaction (e.g. panic), the most common were considered to be displacement to other areas or disturbance of particular behaviours.

A population based criteria to determining the consequence of disturbance was deemed desirable, taking account of the following points:

- If the conservation status is favourable the population size must not be negatively affected;
- If the conservation status is not favourable the growth of the population must not be affected, i.e. the ability to achieve good conservation status must not be compromised; and
- The long term survival of local populations must not be compromised.

The report considered that an acceptable level of disturbance may be determined. To do so, a model (reproduced below as Figure 22) was applied, to enable population level effects to be tracked back through the model and a maximum tolerated sound exposure derived for a given activity.

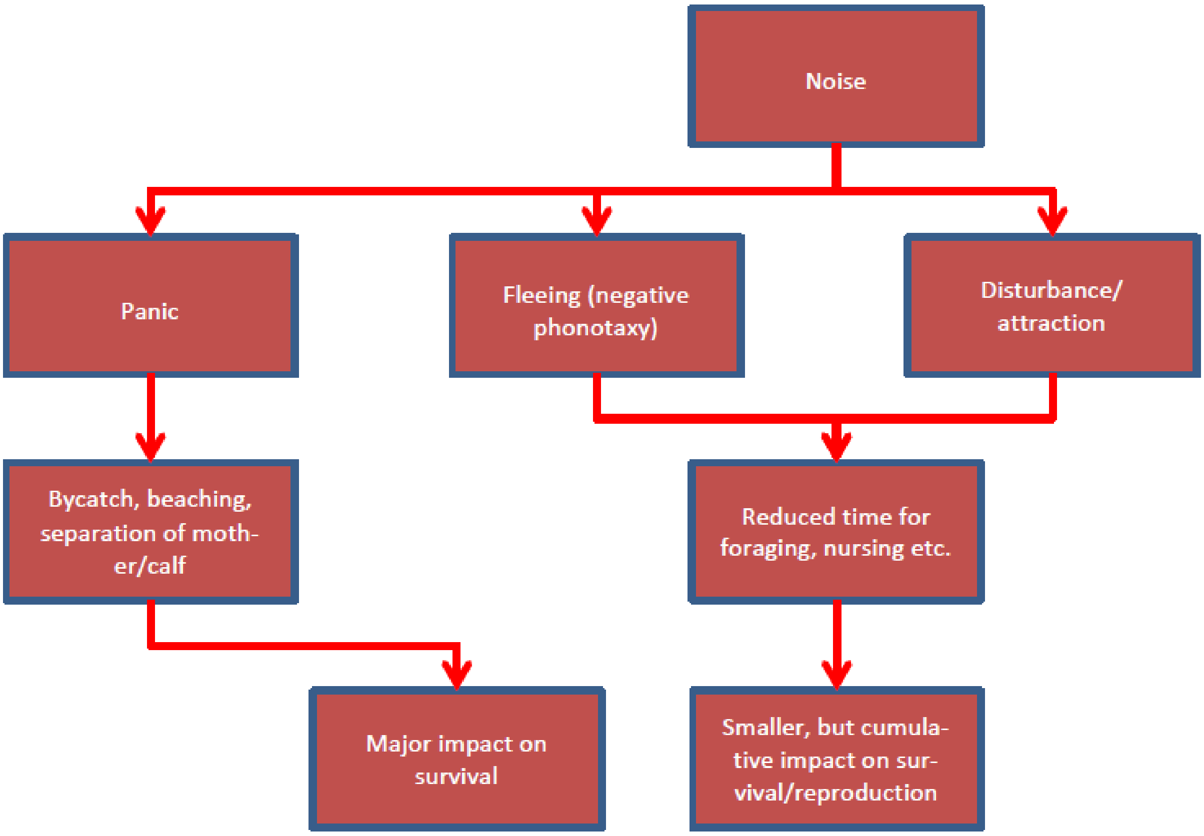

Figure 22: Schematic illustration of mechanisms by which noise-induced changes to behaviour can lead to effects on short-term and long-term survival and reproduction (fitness) in marine mammals

The report references a number of studies that investigated the behavioural reactions of harbour porpoise to piling noise, with Dähne et al. (2013) considered the most reliable. A fleeing response in harbour porpoise was noted from that paper as being recorded at 140 dB re 1 $\mu Pa^2 s$ single pulse SEL, unweighted.

For seals, very limited data were sourced, with a single study referenced on ringed seals in the Arctic (Blackwell et al. 2004). No reaction threshold could therefore be established for seals.

The recommendation was for a set threshold of 183 dB cumulated SEL (unweighted) for harbour porpoise and 200 dB cumulated SEL (unweighted) for seals. The approach to be accompanied by initial use of pinger and subsequent seal scarer if required, with the calculation of cumulated SEL including both the effect with and without pinger/seal scarer but also including the effect of animal fleeing behaviour.

The potential for a population level effect to result from disturbance, specifically the connection between an immediate behavioural response and the ecological consequences of that response, was acknowledged as being the largest knowledge gap for the report.

Underwater noise and marine mammals (Energinet.dk, 2015)

This report was issued in April 2015 by Energinet.dk as revision 4. The purpose of the document was to ensure that the recommendations and guidelines established by the 2014 working group, with respect to piling noise and marine mammals, were incorporated into the EIA studies for six Danish offshore wind farms, with the conclusions of the document to form the background to assessment at those six projects.

The report describes thresholds to apply for assessing PTS, TTS and behavioural response in marine mammals, with the threshold for behavioural response in harbour porpoise given as 140 dB re 1 μPa SEL (single strike) (a reduction from the previous 145 dB re 1 μPa SEL, source for the value not referenced). The behavioural response threshold given for harbour seal and grey seal was the previous value of 171 dB re 1 μPa SEL, with the working group not able to establish such a value given the limited data for seal response to disturbance.

Noise impacts were modelled, taking account of the site specific noise propagation characteristics but also the site specific density of harbour porpoise and seals (where available, with the values drawn from project literature). With regard to seals, the report notes that in general there are insufficient observations of seals in Danish waters to enable seal density at sea to be calculated. While some projects were able to estimate seal density using reference values from the German North Sea, the report notes that one project applied a conservative density derived from the seal population in the area.

The cumulative noise dose for fleeing animals was then calculated, using the thresholds as well as the piling procedure and noise propagation model. Further, different starting distances for the animals were applied (1 m, 1 km and 2 km) to enable the influence of seal scarers to be taken into account when considering overall exposure. Table 1213 below summarises the information presented in Table 4 of the report, providing the average cumulative SEL modelled to be experienced by a fleeing animal, for each of the projects and for each of the three starting distances (with the caveat that the report noted that '*figures for seals are based on distances which are not scientifically founded*').

Table 1213: Calculation of the unmitigated cumulative sound exposure level (SEL) experienced by fleeing animals

Harbour Porpoise

Offshore Wind Farm	SEL_{cum} at 1 m (dB re 1μPa²s)	SEL_{cum} at 1 km (dB re 1μPa²s)	SEL_{cum} at 2 km (dB re 1μPa²s)
Bornholm	214.4	192.1	188.2
Vesterhav Nord	214.3	192.5	189.2
Vesternav Syd	214.4	193.5	190.5
Sejero	213.6	174.9	170.5
Smalandsfar vandet	213.6	169.4	161.1
Saeby	213.8	183.5	181.1

Seals

Offshore Wind Farm	SEL_{cum} at 1 m (dB re 1μPa²s)	SEL_{cum} at 1 km (dB re 1μPa²s)	SEL_{cum} at 2 km (dB re 1μPa²s)
Bornholm	214.4	192.1	188.2

Offshore Wind Farm	SEL_{cum} at 1 m (dB re 1μPa²s)	SEL_{cum} at 1 km (dB re 1μPa²s)	SEL_{cum} at 2 km (dB re 1μPa²s)
Vesterhav Nord	214.3	192.5	189.2
Vesterhav Syd	214.6	195.5	192.7
Sejero	213.6	174.9	170.5
Smalandsfar vandet	213.6	169.4	161.1
Saeby	213.8	183.5	180.5

Numbers of animals potentially affected are then summarised per project, with values on PTS and TTS presented for harbour porpoise and seals but numbers for disturbance presented for harbour porpoise only. The information for unmitigated noise is presented on a worst case basis, with mitigated values presented for each of the 3 starting distances. Mitigation clearly reduced the number of harbour porpoise predicted to be disturbed, and as would be expected the greater the noise reduction at source, the fewer individuals were predicted to be disturbed.

The need to limit risk of PTS seemed to be the main driver behind the noise mitigation applied (seal scarers first, followed by reduction at source if required), with site specific harbour porpoise density (specifically presence of a 'kernel area') indicating whether additional mitigation should be applied to reduce risk of a behavioural effect.

Guideline for underwater noise – Installation of impact-driven piles (Center for Energiressourcer, 2016)

This document was published by Center for Energiressourcer in April 2016 and relates to how the concession holder must demonstrate how they intend to fulfil the requirements on environmental impact caused by emitted underwater noise, as set out by The Danish Energy Agency. The purpose is to estimate the environmental impact from the sound, taking account of source levels and sound propagation loss, to enable the cumulative SEL experienced by a fleeing receptor (marine mammal) to be calculated for the entire piling duration. The cumulative threshold (defined as 190 dB, but no source for the level referenced) should not be exceeded, with mitigation to avoid that occurring if necessary. Such mitigation may be identified at the outset or in response to recorded noise levels during piling.

Updated Conservation Plan for the Harbour Porpoise *Phocoena phocoena* in the Netherlands: Maintaining a Favourable Conservation Status

The conservation plan was published by the Ministry of Agriculture, Nature and Food Quality in 2020, to provide an overview of research, policy and legal developments together with priorities for action. One of the key recommendations relates to underwater noise.

There are four Natura 2000 sites within the Netherland North Sea, with the conservation objective referred to being 'maintain extent and quality area for maintaining the population'. The conservation status (as of 2019) was noted as unfavourable or unknown (depending on the parameter).

Recommendations for underwater noise include a number that are relevant to disturbance and/or management of underwater noise, with reference made to a SEL threshold at 750 metres for piling at OWFs. That level is currently set at 168 dB re 1 μPa^{2}s at 750 m (unspecified if single strike or cumulative) from the source (assuming wind turbines of 10 MW).

Appendix 5: HRA disturbance examples

Thanet Extension Offshore Wind Farm

Thanet Extension OWF was a project proposed as an extension to the existing Thanet OWF, located off the Kent coast in England. The Secretary of State (SoS) issued his decision in June 2020, and refused development consent. With respect to the HRA, however, the SoS agreed with the applicant; that no adverse effect alone or in-combination would result. HRA matters under consideration included the Southern North Sea SAC, a site designated solely for harbour porpoise. The conservation objectives for the site are as follows:

To ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining Favourable Conservation Status (FCS) for Harbour Porpoise in UK waters. In the context of natural change, this will be achieved by ensuring that:

1. Harbour porpoise is a viable component of the site;

2. There is no significant disturbance of the species; and

3. The condition of supporting habitats and processes, and the availability of prey is maintained.

The approach to assessing underwater noise, specifically in relation to disturbance, drew on the advice available at that time (JNCC 2016); that advice has since been updated (JNCC et al, 2020a) and is summarised above (including the evidence base). The approach followed for assessing disturbance therefore applied the EDR approach, specifically 26 km for piling, 5 or 10 km for seismic survey and 26 km for UXO clearance.

The EDR approach is habitat focused – effectively seeking to ensure that sufficient undisturbed habitat remained. Although the citation provides a population for the site (11,864 - 28,889), the conservation advice is clear that '*the harbour porpoise in UK waters are considered part of a wider European population and the highly mobile nature of this species means that the concept of a 'site population' is not considered an appropriate basis for expressing Conservation Objectives for this species*'. Hence the need for a habitat based approach.

Therefore, although the ES applied different animal based measures for the assessment of harbour porpoise disturbance, the HRA assessment followed the habitat based guidance recommended for the designated site. To avoid an adverse effect, no more than 20% of the seasonal area (the SNS SAC being effectively considered as separate summer and winter areas) could be disturbed per day (24 hours) as estimated using the EDR, with no more than 10% of the seasonal area when averaged across the season (which for Thanet Extension was limited to the winter season only (October to March inclusive)). That approach was applied to all relevant activities (with EDR values for UXO clearance, survey and pile driving, with vessel traffic and seabed preparation covered separately) alone and in-combination.

The EDR values applied came from the JNCC guidance then available (since updated in JNCC et al, 2020) but effectively resulted in a series of circular footprints centred around each activity. These had a range of 26 km (for piling and UXO clearance) and 5-10km (for survey works). The area affected on a daily basis (the 20% value) and as averaged across a season (the 10% value) were then calculated for a variety of scenarios for the project alone and in-combination.

The lack of an EDR for the seabed preparation activities resulted in a review of the source levels for such activities, together with potential for a behavioural response to such noise by harbour porpoise. The report concluded no adverse effect on the basis that the effect would (at most) be small scale and localised, as well as being significantly less than the effect during piling.

For the activities for which an EDR was available, it was clear that for the project alone the location of the project was such that there was no possibility of the thresholds being exceeded and therefore no risk of an adverse effect. In-combination, as is common on an offshore windfarm project, the picture was slightly less clear. Effectively, the potential for an effect relates to which other projects are undertaking similar works in proximity to the SNS SAC within the same season. Given the timeframe of the project, that requires assumptions to be made several years in advance as regards which projects will build in that timeframe, which is inevitably subject to significant uncertainty. The approach taken was to allocate projects to tiers, based on certainty. The higher the tier, the more certainty there was that a project will progress. However, the more tiers are added to the assessment, the greater the risk of threshold exceedance.

The uncertainty in-combination is difficult to address, being outside the control of the applicant; however, there are measures that can be taken at project level to avoid a threshold exceedance if needed. Which measures (if any) are ultimately required would only become clear closer to the point of construction. The response to this uncertainty was to draft a Site Integrity Plan (SIP), which effectively ensured the risk would be revisited on an agreed timeframe, with measures attached to remove the risk of threshold exceedance if required.

The approach therefore delivered on the conservation objectives for the following reasons:

- Applied a definition of significant disturbance through the thresholds (20% per day, 10% across a season);
- Determined the potential for the project to result in significant disturbance for all relevant activities (through the application of EDRs);
- Provided certainty that for the project alone, no significant disturbance would result; and
- In-combination, the uncertainty over time was addressed through a SIP, provided for within the draft DCO and therefore legally binding, providing certainty of no significant disturbance in-combination.

Review of Consented Offshore Wind Farms in the Southern North Sea Harbour Porpoise SAC

The document was published in September 2020 by BEIS and relates to the same designated site as that assessed in the Thanet Extension OWF information provided above. The purpose of the document was to review consented offshore wind farms, where those consents predated the designation of the site (and therefore would not have been included within the HRA process at the time of consent). The report considers those projects both alone and in-combination.

As the designated site is the same as that considered above (the SNS SAC), the information on the site and relevant guidance are not repeated here.

With respect to piling, the report presented a summary of the effect of bubble curtains on the range across which disturbance was predicted to arise (Bellmann 2014). That table is reproduced below as Table 1415.

Table 1415: Influence of Bubble Curtains on Predicted range and Area of Disturbance

Bubble curtain type	**Average distance (km)**	**% difference in distance**	**Average area (km^2)**	**% difference in area**
No bubble curtain	40.1	0	5,352	0
Big Bubble Curtain (BBC)	17.9	55.4	1,022	80.9
Little bubble curtain (LBC)	15.2	62.1	732.4	86.3
Small bubble curtain (SBC)	6.7	83.3	142.8	97.3
Double Big Bubble Curtain (DBBC)	5.2	87.0	86.8	98.4

With respect to noise thresholds for disturbance, the report references Southall et al (2007) (together with the subsequent NMFS 2016, 2018 and Southall et al, 2019) as being unable to define a threshold for disturbance as there was no clear relationship between the received sound level and behavioural response. The report went on to reference Lucke et al (2009), specifically the unweighted SEL 145 dB re 1uPa^{2}s for aversive behaviour (with that level applied for the assessment of potential displacement within the report).

Further, the report referenced studies (referencing Brandt et al. 2016) that demonstrated a higher behavioural response to higher received sound levels, enabling a dose response curve to be developed from which the proportion of individuals displaced at any given received sound level could be calculated. That curve is reproduced below as Figure 23. Based on the results from the dose response curve, it was estimated that there is approximately a 25% probability of displacement occurring at the unweighted SEL of 145 dB re 1uPa^{2}s threshold.

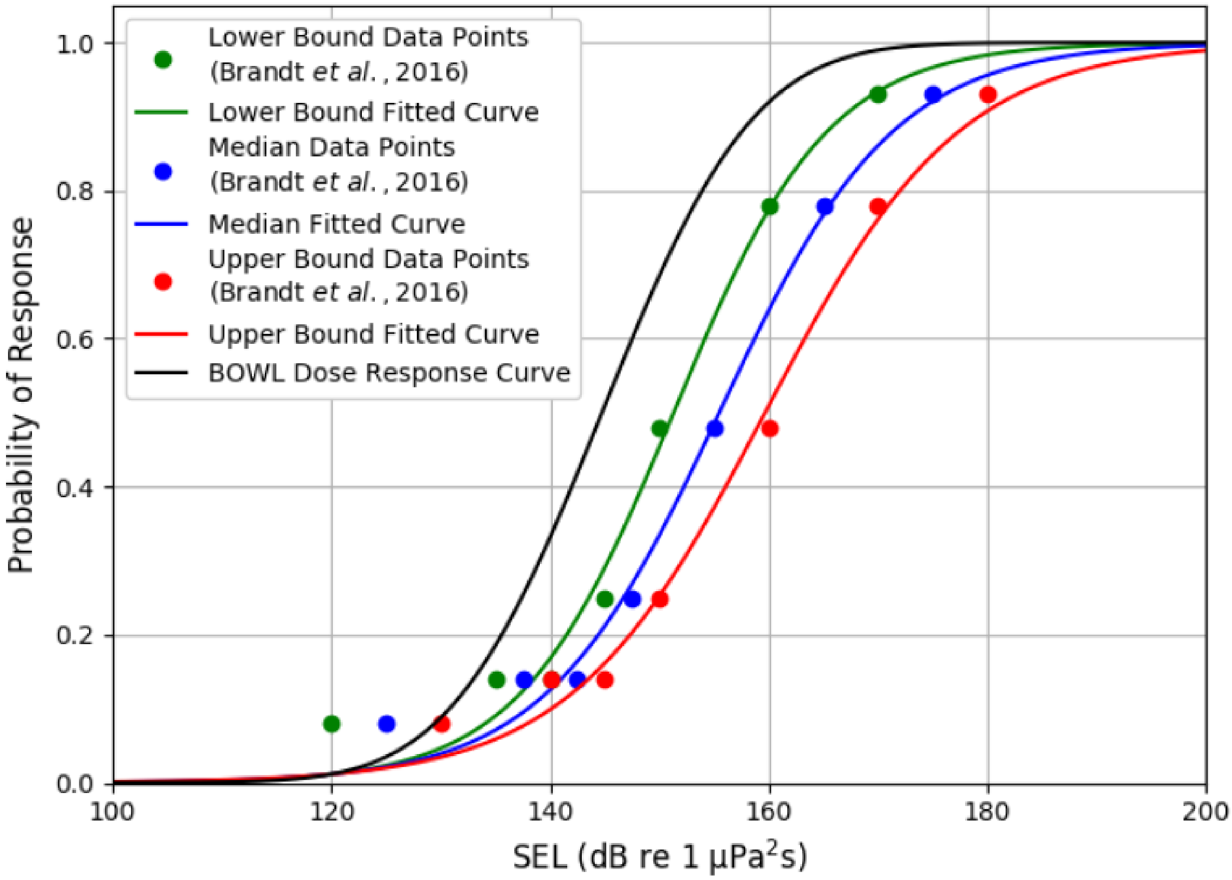

Figure 23: Behavioural response curves considered for assessing potential behavioural disturbance to harbour porpoise

It should be noted that the data used to inform the curve includes that from projects where bubble curtains were used, but also includes data from projects that were used to inform the 26 km EDR (Tougaard et al. 2013, Brandt et al. 2016).

Reference to the EDRs within SNCB guidance (JNCC 2020b) is made, noting that BEIS had been advised that the use of EDRs and thresholds should be used within the assessment. It also, however, notes that SNCBs '*recognise that future data may require the suitability of the EDR to be reconsidered if it is found to be inappropriate*'.

Modelling was then applied for piling, seismic survey, sub-bottom profiler and UXO detonation and blasting to determine the potential behavioural disturbance to harbour porpoise. Firstly, the modelling applied the disturbance threshold (145 dB re 1uPa^{2}s, from Lucke et al. (2009) and Thompson et al. (2013a)), followed by the application of the dose response curve across different received SEL bands.

For piling and on a project by project basis, the report presented the distances and area within which displacement or disturbance was predicted to occur from pile driving.

Modelling was also undertaken for seismic survey (with soft start), with very different results depending on location (and noting that the air gun survey modelled is not typical of surveys undertaken for an OWF). No disturbance ranges were presented for UXO clearance, based on '*activities that make use of explosions for a relatively short period of time it is considered that there will be a low likelihood of disturbance*' (JNCC 2010).

As regards the assessment approach applied, although the report notes that JNCC advise that it is not appropriate to use the site population estimates in any HRA, the report found that there are no formal thresholds above which an impact is predicted to be adverse. A threshold of 1.7% of the relevant population (deemed to be the Management Unit population in the report) is defined (drawing Defra (2003), (ASCOBANS 2015) as being the level above which a population decline would be inevitable (referred to here as the ASCOBANs derived threshold). An equivalent level of impact from disturbance, which is temporary and considered non-lethal, would be expected to have a lower level of impact on the population. The calculations of numbers disturbed (were based on the dose response curve and the project specific individual density. The 20%/10% threshold approach published by JNCC et al (2020b) was also referenced and assessed as a method of determining adverse effect, with that detail not repeated here as the approach is discussed in the context of Thanet Extension above. The assessment presented in the report was made on both the ASCOBANs derived threshold and the SNCB threshold.

The in-combination assessment followed a tiered approach and considered a number of possible scenarios. The assessment process followed included both the 20%/10% SNCB threshold and the 1.7% ASCOBANs derived threshold, with the requirement for a SIP noted to manage any in-combination uncertainty.

The approach therefore delivered on the conservation objectives for the following reasons:

- Applied a definition of significant disturbance through the SNCB thresholds (20% per day, 10% across a season);
- Applied a definition of significant disturbance to individuals through the ASCOBANs derived threshold at Management Unit population level;
- Determined the potential for the projects to result in significant disturbance for all relevant activities and for a variety of scenarios;
- Provided certainty that for each project alone, no significant disturbance would result; and
- In-combination, the uncertainty over time was expected to be addressed through a SIP at project level, to be attached to each Marine Licence by the MMO and therefore legally binding, providing certainty of no significant disturbance in-combination.

Projet de Parc Eolien en Mer de Saint-Nazaire:Evaluation des incidences Natura 2000

The document presents a French HRA for an OWF, published in 2015. The document considered (among non marine mammal features) minke whale, bottlenose dolphin, harbour porpoise and grey seal. The assessment addressed both physical injury (which included PTS) and a fleeing response.

The potential range of impact was determined through underwater noise modelling, with the assessment for harbour porpoise assuming that 60% of individuals would flee as soon as the exposure threshold exceeded 145 dB SEL (assumed to be dB re 1μPa^{2}s from the accompanying figures), with modelling predicting a range up to 13.2 km from source, increasing to 20 km for concurrent piling. Harbour porpoise were considered capable of swimming at speeds of up to 7.1 km/hr to flee.

The potential for impact was found to be negative but temporary, with mitigation recommended including soft start and ADDs to limit the risk of injury.

Bottlenose dolphin and harbour porpoise were noted as being included within the relevant SCI (Site of Community Importance)s / SACs as groups passing through or feeding; the functionality of the sites was therefore not considered to be significant for the conservation of these mammals. The significance of disturbance was considered in light of the experience from other OWFs, specifically that desertion of a site had not been observed. With mitigation to address the risk of injury, the species were considered tolerant of displacement. The conclusion for marine mammals was found to be not significant.

It is assumed that the report delivered on the conservation objectives in the following ways:

- Populations of bottlenose dolphin and harbour porpoise considered transitory, with the sites not being considered significant for nature conservation of the species;
- The potential for impact from disturbance considered to be temporary; and
- No evidence of long term displacement from elsewhere with good tolerance for displacement assumed.

Swedish Court of Appeal Case 2014-M 6960

The document summarises a court case regarding an OWF in Swedish waters, and presents a high level overview of the approach taken to management of underwater noise (among other matters). With regards to Natura 2000, the application of the German approach to management of underwater noise was deemed sufficient to avoid disturbance of harbour porpoise, with limited potential for a local temporary displacement of individuals. Further, as it was not possible to predict the movement of harbour porpoise in the area, a timeframe for when no disturbance would occur could not be determined.

Specific requirements included the following:

- Piling, blasting and drilling may not be carried out during the period 15 December - 31 May (no reason given in the document);
- Underwater noise levels must not exceed any of the following: SEL 160 dB re 1 uPa^2 s at a distance of 750 meters from the sound source OR SPL peak 190 dB re 1 uPa at a distance of 750 meters from the sound source;
- Porpoises should not be within a 750 meters radius from activities which give rise to noise levels above SEL 160 dB re 1 uPa^2 s, during the entire construction and decommissioning phases;
- During construction and decommissioning phases, cumulative effects are relevant, e.g. piling resulting in loud underwater noise should not be carried out simultaneously or in series with other noisy activities (e.g. military exercises or other piling) in the same sea area; and
- Ramp up and deterrent devices should be used before starting noisy activities.

It is assumed that the assessment made for the OWF was deemed compliant with the conservation objectives, although these were not specifically stated in the document.

Dundee Local Development Plan 2

The Local Development Plan draft HRA Record was published by Dundee City Council in June 2017. The report records that it is a legal requirement for Plans to record their effects on European Sites, and references the SNH document 'Guidance for Plan-Making Bodies in Scotland (version 3, 2015), which was used to guide the HRA for the proposed Dundee Local Development Plan.

A number of relevant sites were identified for consideration, including the Moray Firth SAC (bottlenose dolphin) and the Isle of May (grey seal). The focus of the current section is on how grey seal were assessed – however, if pertinent points in relation to bottlenose dolphin are made, these are also noted.

The Conservation Objectives for the site were provided as follows:

- To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features; and
- To ensure for the qualifying species that the following are maintained in the long term:

  - Population of the species as a viable component of the site
  - Distribution of the species within site
  - Distribution and extent of habitats supporting the species
  - Structure, function and supporting processes of habitats supporting the species
  - No significant disturbance of the species

The Appropriate Assessment was presented in tabular format of the report. With respect to piling noise, it was noted that (for grey seal and bottlenose dolphin) significant disturbance could result, potentially sufficient to change the distribution of the species and their prey within their natural range. The potential for effect was not quantified, with mitigation required to avoid an adverse effect (in the form of the submission and approval of a satisfactory piling strategy). The same mitigation based approach was taken to the assessment of disturbance from tourism and leisure activity or construction vessels – the requirement for management plans to be submitted that avoid significant disturbance.

The approach therefore delivered on the conservation objectives for the following reasons:

- Identified potential relevant effects and activities that could cause them; and
- Ensured a requirement for mitigation, subject to approval and sign off, to prevent significant disturbance.

Wylfa Newydd Project

The shadow HRA for the Wylfa Newydd Nuclear Power Station project was prepared by Horizon Nuclear Power in 2018, and relates to a project located on Anglesey in north west Wales. The report included consideration of grey seal in relation to a number of designated sites (not all of which being in Welsh waters), including Pen Llŷn a'r Sarnau/Llŷn Peninsula and the Sarnau SAC, Bae Ceredigion/Cardigan Bay SAC, Sir Benfro Forol/Pembrokeshire Marine SAC, The Maidens SAC, Lambay Island SAC and Saltee Islands SAC.

The conservation objectives applied for grey seal were as relevant to individual designated sites (with those for Welsh SACs provided in Appendix 3: Overview of the HRA Process and SACs in Welsh Waters: Marine Mammal SACs in Welsh Waters). The relevant objectives therefore relate to long term maintenance of the population, the natural range of the population and the supporting habitats and species, all in the context of Conservation Status. Guidance referenced for marine mammals and underwater noise related to mitigation for piling noise and reducing the risk of injury, as provided by JNCC.

Underwater noise modelling was carried out on relevant activities (drilling, dredging, rock breaking/cutting, vessel movement), to determine the predicted range of effect for onset of PTS (based on Southall et al, 2007) and disturbance. The disturbance threshold was considered from a number of references, with the value applied for phocids in water for behavioural avoidance being 172 dB re 1μPa^{2}s (Finneran and Jenkins 2012). The thresholds applied for behavioural avoidance in mid frequency and high frequency cetaceans were also from Finneran and Jenkins (2012); weighted SEL 167 dB re 1μPa^{2}s and 141 dB re 1μPa^{2}s respectively. Lucke et al (2009) was used to define a minor behavioural effect in harbour porpoise at 145 dB re 1μPa^{2}s (single strike unweighted SEL). It is understodd that NRW provided advice to the project with respect to the use of TTS as a proxy for disturbance (NRW, pers. comm.).

The number of grey seals within that range were presumably calculated based on the potential area of effect (determined by underwater noise modelling) and the estimated grey seal density value across the project Development Area (0.16 individuals per km^2). That number was then compared to the reference population (6,000) and the most recent site based population (from 2002, 365 individuals). The reference population was deemed more appropriate, as the site based individuals formed part of the wider population.

The report found that the maximum predicted range for PTS would be in relation to rock breaking, with that found to be up to 450 m. The assessment concluded that this would have the potential to affect 0.15 grey seal (0.0025% of the MU population). Further, during construction, the number of grey seal that could be temporarily disturbed as a result of underwater noise would be up to a maximum of 20.5 individuals (up to 0.3% of the reference population). The assessment was primarily based on the effect being temporary, and that the proportion of the reference population affected would be small. In light of the assessment, the shadow Appropriate Assessment concluded that there would be no adverse effect on the integrity, alone or incombination with other plans and projects, for grey seal associated with the identified designated sites at any stage of the Project.

For reference, the HRA also considered bottlenose dolphin and harbour porpoise SACs. For bottlenose dolphin, the assessment approach followed that applied for grey seal (albeit with different thresholds), with the approach for harbour porpoise based on area of the

SAC that may be disturbed as a percentage of the total SAC (based on area within modelled range of thresholds applied).

Although the Application was withdrawn before a decision was made, the Examining Authorities Report (written in July 2019) was published in February 2021 in the interests of transparency. In relation to effects on SACs where marine mammals are a qualifying feature, the ExA recommended that 'AEoI can be excluded, provided the relevant mitigation is secured through the DCO as a Marine Licence will not be granted before the DCO is consented'.

The report delivered on the conservation objectives in the following ways:

- Although not specifically cross referenced to the conservation objectives, a temporary disturbance (not injury) effect on a small proportion of the overall population was deemed unlikely to affect long term maintenance of the grey seal population;
- Wider effects not directly linked to noise (e.g. the land take area) is such that the change is so small and the number of individual seals that could be affected so low that no adverse effect on the conservation objectives was found; and
- Inclusion of mitigation as required.

Nigg Bay Harbour Facility Habitat Regulations Assessment

Aberdeen Harbour Board submitted an application to develop a new harbour facility at Nigg Bay, Aberdeen. The proposals resulted in South Harbour Expansion, the 'largest marine infrastructure project currently underway in the UK'. The documents reviewed are primarily the project HRA, dated November 2015, and the Appropriate Assessment undertaken by Marine Scotland in 2016. A number of SACs were identified, with the focus of this review being the approach taken to the Moray Firth SAC, specifically in relation to bottlenose dolphin.

The relevant Conservation Objectives for the Moray Firth SAC are as follows:

- To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features; and
- To ensure for the qualifying species that the following are established then maintained in the long term:
    - Population of the species as a viable component of the site
    - Distribution of the species within site
    - Distribution and extent of habitats supporting the species
    - Structure, function and supporting processes of habitats supporting the species
    - No significant disturbance of the species

Bottlenose dolphin were identified as being present in Nigg Bay year round, with photo ID demonstrating that at least some are associated with the Moray Firth SAC. The site falls within the East Coast Management Unit, with the assessed condition of the bottlenose dolphin population within the Moray Firth SAC noted as being Favourable Recovered. The project HRA noted that in 2012 to 2013, 60%, of the total Scottish east coast bottlenose dolphin population were using the area between Aberdeen and the Firth of Forth (Quick et al. 2014). Further, that the JNCC (2013) stated that 64% of the Scottish east coast bottlenose dolphin population are known to utilise the Moray Firth site (Cheney et al. 2013).

Disturbance from underwater noise was noted as potentially occurring during construction (blasting, drilling, impact piling and dredging). Modelling was carried out to predict underwater noise, and reported on in the project specific Underwater Noise Impact Study. The technical report cited a number of studies that investigated behavioural reactions to underwater noise, citing the following unweighted metrics for behavioural thresholds:

- Level B Harassment (see Appendix 1: Thresholds used for behavioural impact assessment for definition) states that sound has "*the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild*".
  - For impulsive sounds, this threshold has been set at 160 dB re 1 μPa SPL while for continuous sounds the threshold is 120 dB re 1 μPa SPL (NMFS 1995);
  - Low Level Disturbance to impulsive sounds where the threshold has been set at 140 dB re 1 uPa SPL (NMFS 1995).

A summary of the exposure limits applied with respect to marine mammal disturbance in the report is provided in Table 16.

Table 16: Disturbance criteria applied for cetaceans and pinnipeds

Exposure limit	**Effect**
$L_{p,pk}$ 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise
SPL 160 dB re 1 μPa	Level B – Harassment in cetaceans and pinnipeds exposed to impulsive sounds
SEL 145 dB re 1 $\mu Pa^2 s$	Aversive behavioural reaction in harbour porpoise
SPL 140 dB re 1 μPa	Low level disturbance in cetaceans and pinnipeds exposed to impulsive sounds
SPL 120 dB re 1 μPa	Level B – Harassment in cetaceans exposed to continuous sounds

The modelled results for the different activities are summarised in Table 17 below.

Table 17: Summary of modelled results for disturbance thresholds (modelled range)

Trailling Suction Hopper Dredger Vessel Spread

Exposure limit	Effect	Winter	Summer
$L_{p,pk-pk}$ 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise	23 m (38-100 m at breakwaters)	23 m (33-100 m at breakwaters)
SPL 120 dB re 1 μPa	Level B-Harassment in cetaceans exposed to continuous noise	44.4 km (39-59km at breakwaters)	26.4 km (27.2-28 km at breakwaters)
SEL 145 dB re 1 uPa^2s	Aversive cumulative SEL	>10 km	>10 km

Back hoe Dredger Vessel Dredging Spread

Exposure limit	Effect	Winter	Summer
$L_{p,pk-pk}$ 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise	390 m (340-357 km at breakwaters)	390 m (340-357 m at breakwaters)
SPL 120 dB re 1 μPa	Level B-Harassment in cetaceans exposed to continuous noise	56 km (47-59 km at breakwaters)	34 km (33-37 km at breakwaters)
SEL 145 dB re 1 uPa^2s	Aversive cumulative SEL	>10 km	>10 km

Drilling Vessel Spread

Exposure limit	Effect	Winter	Summer
Lp,pk-pk 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise	50-52 m at breakwaters	50-52 m at breakwaters
SPL 120 dB re 1 μPa	Level B-Harassment in cetaceans exposed to continuous noise	37-46 km at breakwaters	26-30 km at breakwaters
SEL 145 dB re 1 uPa2s	Aversive cumulative SEL	>10 km	>10 km

Piling Vessel spread

Exposure limit	Effect	Winter	Summer
$L_{p,pk-pk}$ 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise	1220-1344 m at breakwaters	1060-1239 m at breakwaters
SPL 160 dB re 1 μPa	Level B-Harassment in cetaceans exposed to impulsive noise	8.2-10.5 km at breakwaters	6-7.3 km at breakwaters
SEL 140 dB re 1 μPa^2s	Low level disturbance in cetaceans exposed to impulsive noise	40-49.2 km at breakwaters	27-30.7 km at breakwaters

Exposure limit	Effect	Winter	Summer
SEL 145 dB re 1 uPa^{2}s	Aversive cumulative SEL	>10 km	>10 km

Seabed Material Disposal

Exposure limit	Effect	Winter	Summer
$L_{p,pk\text{-}pk}$ 174 dB re 1 μPa	Aversive behavioural reaction in harbour porpoise	441-462 m at breakwaters	432-441 m at breakwaters
SPL 120 dB re 1 μPa	Level B-Harassment in cetaceans exposed to continuous noise	51-62 km at breakwaters	35-40 km at breakwaters
SEL 145 dB re 1 uPa^{2}s	Aversive cumulative SEL	>10 km	>10 km

Reviewing the noise modelling results, the Appropriate Assessment noted that the noisy activities associated with the proposed works are likely to cause disturbance or displacement of the species and without mitigation measures could cause injury. The project HRA was clear that it was not possible to provide mitigation to potential adverse displacement and/or low level disturbance effects. Mitigation measures involved location of works (where possible, piling and blasting behind the breakwater) and where location could not be managed a bubble curtain would be deployed (or other method if demonstrated to be more effective). Other mitigation measures included vibro piling, soft start, mitigation zones and limits on piling times on a daily basis to enable marine mammal observers but also to provide time without noise (7am - 7pm Monday to Friday, 9am - 4pm on Saturdays and no percussive piling on Sundays). Measures applied were required to be discussed and agreed with SNH and Marine Scotland.

The project HRA assumed, as a precaution, that bottlenose dolphin would be displaced from the immediate Nigg Bay area for the duration of the 3 year construction phase. Further, the HRA referenced a 49.2 km range for behavioural modification, which was not considered likely to occur (background noise issues, habituation and local geography). The conclusion relied heavily on the existing background noise levels of an SPL of 118-149 dB re 1 μPa over a frequency bandwidth of 10 Hz to 10 kHz (Evans et al. 2008) enabling the conclusion that existing baseline conditions already exceed the threshold level for the Low-level Disturbance criterion and are within 11 dB re 1 μPa of the Level B-Harassment criterion. It was therefore considered likely that individual bottlenose dolphin using Aberdeen Harbour are already habituated to noise conditions indicative of low level disturbance such that displacement over the entire 49.2 km range will not occur.

As regards the important feeding area for bottlenose dolphin at the entrance to Aberdeen Harbour, the risk of disturbance/displacement was associated with piling only. Such works would be intermittent across a 23 month period, with a temporal restriction on piling to daylight hours and excluding Sundays. The local geography (specifically Girdle Ness) was also considered to afford some protection from underwater noise. As the consequences of these factors could not be quantified, full displacement from the area was assumed on an occasional and short lived basis. Reference to alternative known feeding locations was made. The uncertainty necessitated the inclusion of a bubble curtain as additional mitigation, to ensure the localised feeding hotspot would remain available during construction and 'would act as compensation for any displacement from Nigg Bay'. Other feeding hotspots would be unaffected, but greater reliance may be placed on these.

The application of mitigation enabled the project HRA to draw a conclusion of no adverse effect on bottlenose dolphin from displacement/disturbance resulting from construction noise.

The Appropriate Assessment noted that SNH had commented that the planned mitigation should prevent injury and death and limit the level of disturbance and displacement of bottlenose dolphins from their preferred foraging area at the mouth of the River Dee, and of Nigg Bay whilst in transit along the east coast of Scotland such that it would not lead to an adverse effect on their population.

For grey seal, SNH advised that the proportion of the grey seal population from the Isle of May SAC that occurs in Nigg Bay is small and there would not be an adverse effect on the integrity of the SAC population.

The report delivered on the conservation objectives in the following ways:

- The consequences of displacement were not measured in terms of numbers of individuals but rather in minimising the duration and frequency of any displacement/disturbance including ensuring key areas were made available and undisturbed – assumed to apply to the need to avoid deterioration of habitats or significant disturbance.

Natura Impact Statement for the Development of a 1:15 Scale Test Site for Wave Energy Devices at Belmullet Co. Mayo

The report provides the Natura Impact Statement (HRA terminology in Ireland) for a proposed wave energy device at Belmullet, Co. Mayo. The report was published in December 2014.

The screening assessment identified bottlenose dolphin (among other species/habitats) as a feature of the West Connaught Coast cSAC (assumed to reference the West Connacht Coast SAC) with respect to noise, visual and physical disturbance. The relevant conservation objectives for that site are as follows:

- Access to suitable habitat, measured through the number of artificial barriers, with a target that species range within the site should not be restricted by artificial barriers to site use; and
- Disturbance, measured through level of impact, with a target that human activities should occur at levels that do not adversely affect the bottlenose dolphin population at the site.

Consultation on the proposals with the Department of Arts, Heritage and Gaeltacht confirmed that Natura 2000 sites would require consideration under Article 6(3) of the Habitats Directive (Appropriate Assessment), with reference to guidance on undertaking Appropriate Assessment in general and to undertaking assessments of underwater noise for marine mammals specifically. The underwater noise guidance was updated in 2014 and references Southall et al (2007) with respect to marine mammal hearing groups and thresholds and emphasises a risk based approach to assessment.

Key questions to ask in the Risk Assessment process were identified as follows:

- Do individuals or populations of marine mammal species occur within the proposed area?
- Is the plan or project likely to result in death, injury or disturbance of individuals?
- Is it possible to estimate the number of individuals of each species that are likely to be affected?
- Will individuals be disturbed at a sensitive location or sensitive time during their life cycle?
- Are the impacts likely to focus on a particular section of the species' population, e.g., adults vs. juveniles, males vs. females?
- Will the plan or project cause displacement from key functional areas, e.g., for breeding, foraging, resting or migration?
- How quickly is the affected population likely to recover once the plan or project has ceased?

The NIS report includes a marine mammal risk assessment, which identified the following sources of potential noise disturbance (no risk of injury or death):

- Vessel noise during installation and removal of buoys and devices; and
- Noise associated with operating devices.

The criteria applied for behavioural response were derived from Southall et al (2007) and relate to non-pulsed sources. The values given are summarised in Table 18 below.

Table 18: Criteria and values for disturbance/behavioural response from non pulse sources

Species group	**Frequency range for hearing**	**Response Criteria (SPL RL (dB))**
Low frequency cetaceans (baleen whales)	7 Hz - 22 kHz	120-160
Mid frequency cetaceans (most toothed whales, dolphins)	150 Hz - 160 kHz	90-200
High frequency cetaceans (certain toothed whales, porpoises)	200 Hz - 180 kHz	90-170
Pinnipeds (water)	75 Hz - 75 kHz	100+
Pinnipeds (air)	75 Hz - 30 kHz	110-120

The noise levels associated with the devices in operation and vessel movements were considered sufficient to result in a disturbance/behavioural response only. Vessel presence was considered to be infrequent, short term and temporary and, combined with the infrequent use of the area by cetaceans and the low numbers present, result in a conclusion within the Risk Assessment of insignificant risk to marine mammals. The conclusion was supported by existing fishing and vessel activity that occurs in the area without deterring harbour seals on haul out.

The guidance notes that where risk is identified, mitigation is required; no mitigation was identified within the NIS given the conclusion drawn.

The Risk Assessment enabled the NIS conclusion '*noise levels generated by the proposed development will not negatively impact any marine mammals in the area*' and *'the proposed test site in Blacksod will not pose any risk to the bottlenose dolphin populations of the West Connaught Coast cSAC (IE002998) and any other cSACs further afield. There will be no reduction in the natural range of the species and there will continue to be a sufficiently large habitat to maintain its population on a long-term basis and as a result the conservation objectives and overall integrity of these cSACs will not be impacted by the proposed test site*'.

The report delivered on the conservation objectives in the following ways:

- No artificial barrier was identified; and
- An insignificant risk of disturbance was concluded.

Data Archive Appendix: Disturbance methods used in EIAs

Data outputs associated with this project are archived on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A spreadsheet named **EIA disturbance review – final.xls** in Microsoft Excel. It includes a list of each EIA reviewed, identification of whether or not each impact was assessed quantitatively and lists of the thresholds used for each quantitative impact assessment. Download here or contact NRW for a copy.

Further copies of this report are available from library@cyfoethnaturiolcymru.gov.uk