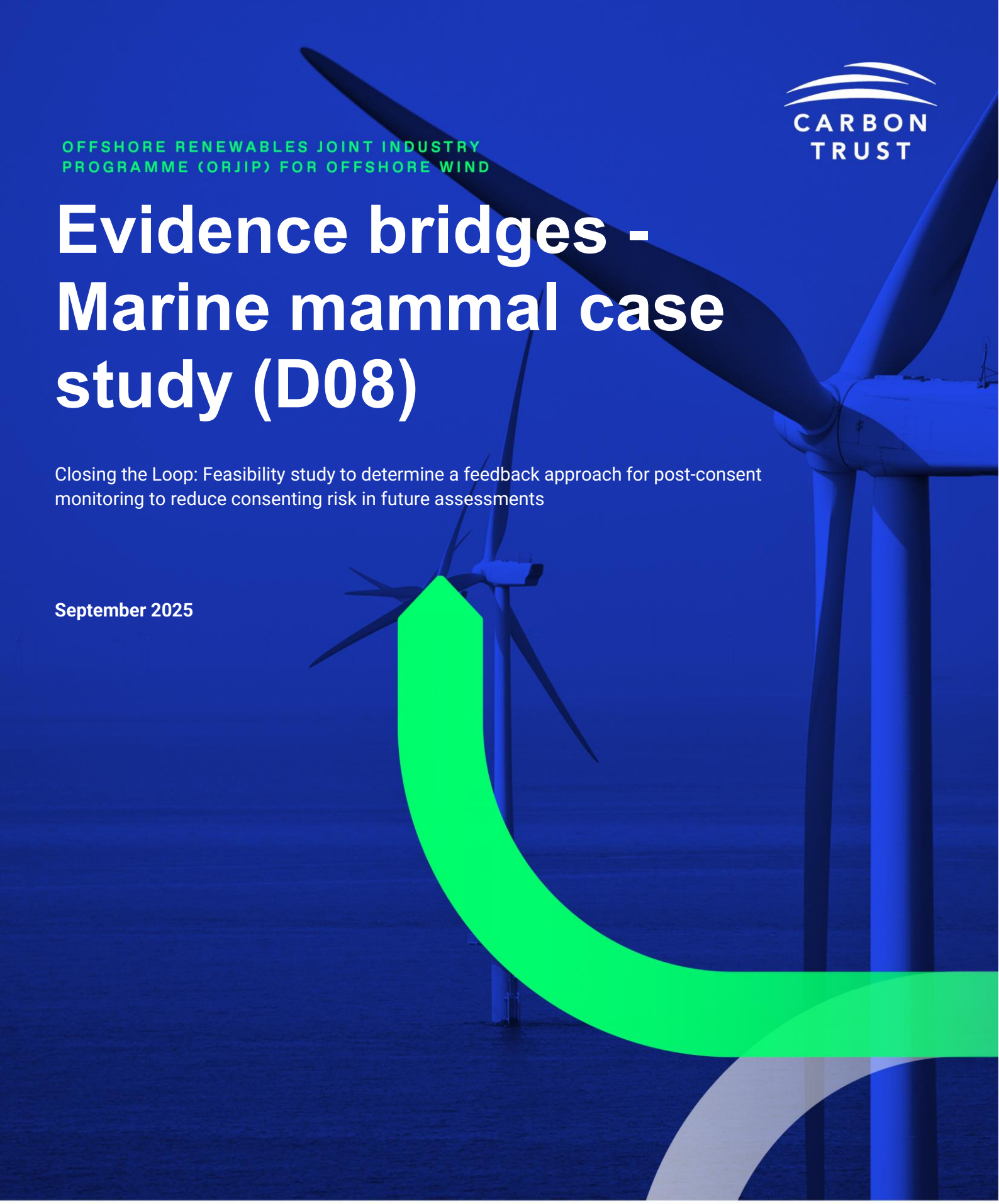

CARBON TRUST

OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

Evidence bridges - Marine mammal case study (D08)

Closing the Loop: Feasibility study to determine a feedback approach for post-consent monitoring to reduce consenting risk in future assessments

September 2025

orjip
working to accelerate offshore consenting

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ORJIP Offshore Wind

The Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind is a collaborative initiative that aims to:

- Fund research to improve our understanding of the effects of offshore wind on the marine environment.
- Reduce the risk of not getting, or delaying consent for, offshore wind developments.
- Reduce the risk of getting consent with conditions that reduce viability of the project.

The programme pools resources from the private sector and public sector bodies to fund projects that provide empirical data to support consenting authorities in evaluating the environmental risk of offshore wind. Projects are prioritised and informed by the ORJIP Advisory Network which includes key stakeholders, including statutory nature conservation bodies, academics, non-governmental organisations and others.

The current stage is a collaboration between the Carbon Trust, EDF Energy Renewables Limited, Ocean Winds UK Limited, Equinor ASA, Ørsted Power (UK) Limited, RWE Offshore Wind GmbH, Shell Global Solutions International B.V., SSE Renewables Services (UK) Limited, TotalEnergies OneTech, Crown Estate Scotland, Scottish Government (acting through the Offshore Wind Directorate and the Marine Directorate) and The Crown Estate Commissioners.

For further information regarding the ORJIP Offshore Wind programme, please refer to the Carbon Trust website, or contact Ivan Savitsky (ivan.savitsky@carbontrust.com) and Žilvinas Valantiejus (zilvinas.valantiejus@carbontrust.com).

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- NatureScot

- Royal Society for the Protection of Birds (RSPB)
- Scottish Government Marine Directorate

This report was sponsored by the ORJIP Offshore Wind programme. For the avoidance of doubt, this report expresses the independent views of the authors.

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Citation

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List of Abbreviations

BEAM	Balance Evidence Assessment Method
EDR	Effective Deterrence Range
EIA	Environmental Impact Assessment
I	Information Reliability
JNCC	Joint Nature Conservation Committee
NGO	Non-Governmental Organisation
ORJIP	Offshore Renewables Joint Industry Programme
OWEC	Offshore Wind Evidence and Change Programme
OWEKH	Offshore Wind Evidence and Knowledge Hub
OWIC	Offshore Wind Industry Council
OWFs	Offshore Windfarms
PCM	Post-Consent Monitoring
R	Relevance
S	Source Reliability
SCOS	Special Committee on Seals
SNCB	Statutory Nature Conservation Body
WoE	Weight of Evidence

1. Introduction

Evidence-based decision making is a critical component of effective conservation and management. The collection and analysis of evidence can be used in many domains and applications, which supports robust planning, consenting and the development of new policy. In the UK and abroad, utilising the best available science or evidence is highlighted as a key pillar in UK statutory nature conservation bodies[1][2][3][4] (SNCBs), policy[5] and in the application of the precautionary principle[6].

In the context of offshore wind consenting processes, there is a drive to ensure that the evidence base is up to date, fit for purpose and that it feeds back into the assessment process and decision making. The collection of data for marine mammals, birds and other taxa is expensive and time consuming and therefore the absence of this feedback loop is indicative of a missed opportunity, a waste of resources and can delay consent decisions and erode confidence in processes. Therefore, there is a requirement for a mechanism that can promote the uptake of evidence into decision making processes (particularly as it relates to consenting decisions for offshore wind) to drive a virtuous cycle.

This work package was developed to deliver an approach for a second receptor group (marine mammals), but also to deliver a focused framework to assist decision makers (with the potential to also support how we can close the loop at a broader scale).

1.1. The "Evidence bridge" approach (Marine mammals case study)

Booth et al (2024) highlights: *"The use of best available science is an iterative process in any domain. A key obstacle is that researchers (who collect and disseminate the latest data or knowledge) and decision makers (who utilise it) are subject to different pressures and drivers. For example, researchers may be incentivised by high impact, peer reviewed papers – which take time to produce and go through peer review and might involve communication biases. There may also be communication challenges in the style of language used in papers (which can be overly technical or inaccessible to a wider audience).*

Conversely, decision makers such as case officers in SNCBs or regulatory roles may work on shorter timelines and lack time to carefully review all of the latest evidence that researchers produce. This can mean that the responsibility to help translate science into decision making (i.e. to assess the weight of evidence) falls between the cracks, resulting in obstacles to the sustainable development of offshore wind."

'Evidence Bridges' can provide an appropriate approach to ensure that science can be translated into decision making, evidence bridges have the following steps (sensu Sutherland, 2022) which can apply to any taxa or domain: These ideas draw elements from expert elicitation a well-established and widely applied statistical approach to condense human judgments to support decision making, whilst

[1] https://publications.naturalengland.org.uk/publication/5830769699454976

[2] https://blogs.gov.scot/marine-scotland/2024/01/11/shaping-scotlands-marine-future/

[3] https://naturalresources.wales/evidence-and-data/how-researchers-can-work-with-us/?lang=en

[4] https://www.nature.scot/about-naturescot/our-work/transforming-how-we-work/evidence

[5] https://www.fws.gov/media/endangered-species-act

[6] https://unesdoc.unesco.org/ark:/48223/pf0000139578

minimising the inherent biases and heuristics that arise in such instances, across all domains (Sutherland, 2022).

ASK: The first step is to establish the need for review of a given topic or scenario or assumption. For example, the effect of disturbance on harbour porpoises or the collision risk probability of an animal with a turbine**.** This step requires working with stakeholders to identify and refine review question both to identify the variables that affect transferability / applicability of studies and consider characteristics that can be assessed via review.

ASSEMBLE: Collate the evidence from peer reviewed and grey literature to assess the agreed question.

APPRAISE: Carry out rapid reviews of the evidence base (Collins et al (2015) by trained expert group and utilise a 'Weight of Evidence' (WoE) approach (see Christie, et al. 2023)(Figure 1).

APPLY: Preparation of a short briefing note on the current state of the evidence and where the weight of evidence lies for a given topic (i.e. whether or not there is evidence to support or refute a particular position or statement).

By assessing both the weight and distribution of evidence can also help highlight the evidence gaps that challenge this process. These evidence gaps therefore would become the highest priority gaps to be filled.

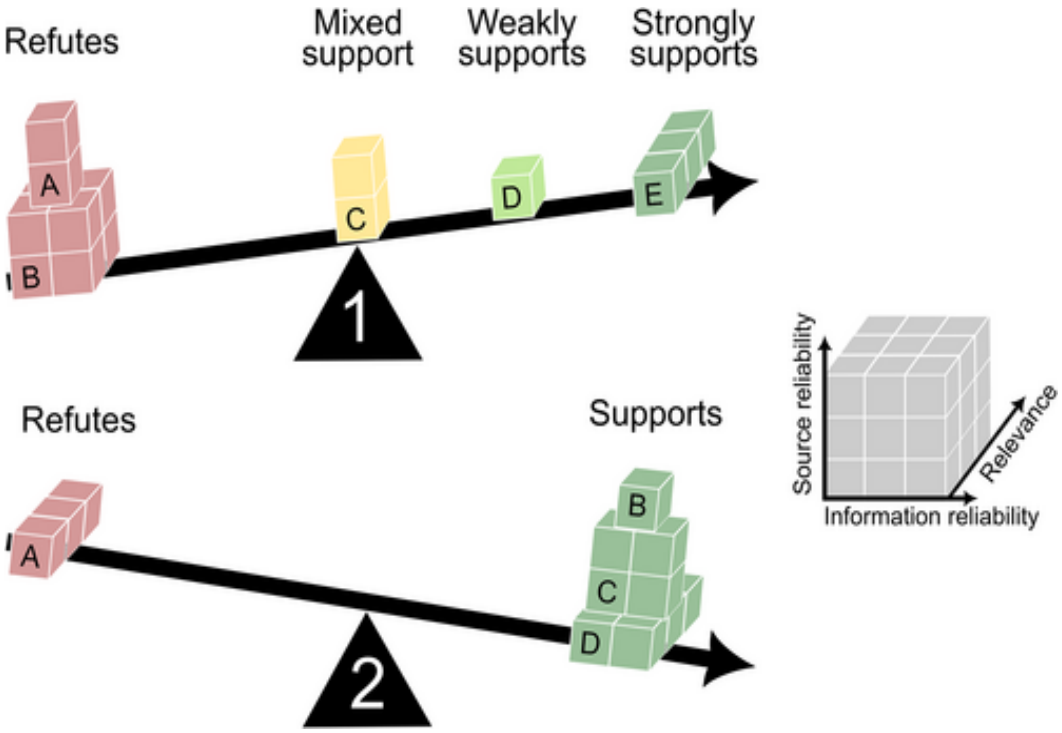

Figure 1 - Reproduced from Christie, et al 2023: "A diagram illustrating the Balance Evidence Assessment Method (BEAM), an intuitive way to visualize weighing different pieces of evidence supporting or refuting an assumption. Note that if the relevance or reliability of a piece of evidence is zero, then the block of evidence has no weight and disappears. Balance 1 shows an assumption that can be assessed by five different pieces of evidence (A)–(E) of varying weights (shown by their size) that can support or refute an assumption on an ordinal scale. Balance 2 shows a situation where an assumption can be assessed by four different pieces of evidence

(A)–(D) that can only either support or refute an assumption (in a binary manner). In many situations, Balance 1 (using an ordinal scale for support) is most likely to be appropriate."

The objective of this work package in Closing the Loop seeks to develop and test a process to bridge the gap between research and decision making – to help ensure the effective translation of evidence to decision making.

2. Methods

Trial participants spanning those who are active researchers, Environmental Impact Assessment (EIA) practitioners, statutory nature conservation body (SNCB) members and government members were approached via a stakeholder engagement phase of this project. The goal of this step was to introduce and describe the process to those represent stakeholders that might benefit from a new evidence synthesis process. This was carried out over Microsoft Teams in individual sessions (i.e. each group was typically met with in isolation). Government and Non-Governmental Organisation (NGO) engagement spanned Natural England, Joint Nature Conservation Committee (JNCC), Department of Environment, Food and Rural Affairs, the Marine Maritime Organisation, Natural Resources Wales, Marine Directorate and NatureScot. Members of the Offshore Wind Industry Council were also engaged through this process, to gather perspective from the offshore wind industry. A member, recently departed from an environmental NGO position, represented the NGO view.

To develop the Evidence Bridge process here, the Balance Evidence Assessment Method (BEAM) framework by Christie et al (2023) was adapted (see the paper for further details). This involved adapting methodology guidance and applying it to a case study on the scale of disturbance to harbour porpoises caused by the installation of monopiles (using impact pile driving). The assumption being assessed was: "The evidence supports that the Effective Deterrence Range (EDR) for harbour porpoises in response to unabated monopile driving is 26 km". This topic was chosen as it represents a high priority topic in offshore wind consenting and because JNCC had commissioned a written review of the evidence base (meaning evidence was being collated in parallel to this study). Participants were provided a two-week window to read and synthesise outputs from the seven pieces of evidence (and complete the WoE assessment). This was extended by 1 week to those who requested an extension.

Seven pieces of evidence were selected as some of the most commonly cited papers or reports used in existing guidance on the EDR topic of the case study – but also represented a variety of survey methods and applications. This is a non-exhaustive list of relevant evidence and was intended to be illustrative (see Brown et al, 2023 for a more complete review). The papers were:

- Benhemma-Le Gall, A., Graham, I. M., Merchant, N. D., & Thompson, P. M. (2021). Broad-scale responses of harbor porpoises to pile-driving and vessel activities during offshore windfarm construction. Frontiers in Marine Science, 8, 664724
- De Jong, C. A. F., Lam, F. P. A., von Benda-Beckmann, A. M., Oud, T. S., Geelhoed, S. C. V., Vallina, T. C., ... & Snoek, R. C. (2022). Analysis of the effects on harbour porpoises from the underwater sound during the construction of the Borssele and Gemini offshore wind farms (No. TNO 2022 R12205). TNO. *(Participants asked to focus on Gemini study only).*

- Brandt, M. J., Diederichs, A., Betke, K., & Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series, 421, 205-216.
- Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., ... & Siebert, U. (2013). Effects of pile-driving on harbour porpoises (Phocoena phocoena) at the first offshore wind farm in Germany. Environmental Research Letters, 8(2), 025002.
- Geelhoed, S. C. V., Friedrich, E., Joost, M., Machiels, M. A. M., & Stöber, N. (2018). Gemini Tc: aerial surveys and passive acoustic monitoring of harbour porpoises 2015 (No. C020/17). Wageningen Marine Research.
- Haelters, J., Dulière, V., Vigin, L., & Degraer, S. (2015). Towards a numerical model to simulate the observed displacement of harbour porpoises Phocoena phocoena due to pile driving in Belgian waters. Hydrobiologia, 756, 105-116.
- Tougaard, J., Carstensen, J., Teilmann, J., Skov, H., & Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). The Journal of the Acoustical Society of America, 126(1), 11-14.

A Microsoft Excel file was developed to assist in the weight of evidence assessment – which included an introduction and guidance to how it was to be completed (see 0 for details). Data from participants was pseudo-anonymised and names deleted (replaced by a letter code). Experts were asked to provide information on the country in which they work, their work role (e.g. EIA practitioner, NGO, Academic researcher, SNCB member, Government scientist). Additionally, experts were asked to self-assess their experience as it relates to the evidence assessment (from 1-10, where 1 = don't feel experienced, 10 = very familiar with the details of the assumption being assessed).

Participants were asked to consider the assumption of: *"The evidence supports that the Effective Deterrence Range for harbour porpoises in response to unabated monopile driving is 26 km"*.

Please note we have selected seven pieces of evidence to minimise the level of effort as the primary focus of this work is to develop this process. In reality there many papers and reports that could support this exercise, but our goal is to test the process more than to review all evidence on this topic.

They were asked to provide ratings (on a four-point scale) for:

1. How well each piece of evidence supports or refutes the assumption,
2. The source reliability of evidence (i.e., how much can the source be trusted?),
3. The information reliability of evidence (i.e., how much can the information provided by the evidence be trusted?), and,
4. The relevance of the evidence (i.e., does this evidence apply to the assumption?).

For each piece of evidence, participants were asked to numerically score (0-3) the evidence source reliability, information reliability, and relevance of the evidence to the statement/assumption being assessed (0). Crucially, participants also provided a nominal score to indicate where on a scale between strong support and strong refutation the evidence should be placed. Participants were also asked to provide narrative feedback on how easy or challenging the process was to follow/execute and provide the time commitment required (in hours). Following the assessment by participants, analysis scripts from Christie et al (2023) were adapted to run in an offline setting – and customisable for future use as this approach evolves. This analysis calculates the weight of evidence based on the S, I and R scores, summing to a maximum score of 27 (3 x 3 x 3) for each piece of evidence (for each rater participant).

For example, if a piece of evidence was scored as S= 2, I=2 and R=3, this would sum to a score of 2x2x3=12 (out of a possible 27) resulting in a weight of evidence score of 12/27 = 0.44. This is repeated for each piece of evidence by each participant, resulting a series of weights.

These weights of evidence can then be stacked on the balance by the degree to which the evidence supports the assumption (i.e. the spectrum from strongly support and strong refutation). This allows the identification of where the balance of evidence sits. The analysis includes generating weighted average for the strength of support (and bootstrapped confidence intervals) to show where the central point of balance lies in the overall support of evidence for the assumption and the confidence around that position.

Participants were weighted equally, and evidence was all weighted equally. Additionally, in determining the balance of evidence (on the spectrum), even weights were applied across all 'strength of support' categories (i.e. 1 unit of evidence for refuting a statement was equal to 1 unit of evidence in support of the statement). Table 1 shows the interpretation key for utilising the outputs of the Evidence Bridge process. It uses equal size bins to split the five categories equally between -2 and +2 (the minimum and maximum scores respectively).

Table 1 - Evidence Bridge Scoring Outcome Interpretation Key

Score	Interpretation
-2 to -1.2	Strongly refute statement being assessed
-1.2 to -0.4	Refute statement being assessed
-0.4 to +0.4	Mixed / Neutral
+0.4 to + 1.2	Support statement being assessed
+1.2 to +2	Strong support statement being assessed

Multiple analyses were completed, first using all data grouped then using experts who had self-assessed their experience to be ≥7 (on a 1-10 scale). Whether different groups might view the evidence in markedly different ways and generate different outcomes in a WoE assessment (given their area of work (e.g. conservation/government vs industry)) was assessed. This was done to determine if the assessment would be strongly biased in one direction due to the participant representation).

3. Results

During the stakeholder engagement process, positive feedback was gathered in support of continuing as proposed in this project. Many government and SNCB members indicated they'd be interested in supporting this process with pointed feedback indicating:

- *"This kind of transparent process is desperately needed".*
- *"Resourcing is always the issue".*
- *"Continued engagement with stakeholders to ensure buy-in is important".*
- *"Transparency and crystal clear outcomes will be needed" i.e. "a clear headline".*
- *"Important this kind of process considers how legal requirements – so evidence needs are clearly understood by all".*
- *"The Special Committee on Seals (SCOS) is the closest example but need more definitive and shorter outputs." & "Could we have a (focused/refined) SCOS for cetaceans?".*

Below (Table 2 and Table 3) we summarise the participants feedback on the Evidence Bridge process. The participants spanned many of the stakeholder groups. Submissions from Government / SNCBs groups was broadly in line with the response rate from other groups – but many individual members highlighted they could not allocate time to work on this (despite interest). As a result, the responses didn't provide a comprehensive coverage across all of the different SNCBs and some organisations were underrepresented This is likely an artifact of the compressed timeline for the assessment – but highlights an important point regarding resourcing/availability of different participants.

Table 2 - Summary of participants in weight of evidence assessment.

Group	# of participation sent	# of Responses
EIA practitioners	2	1
Researchers	6	3
Government / SNCBs	14	5
Environmental non-government organisations	1	1
Industry	1	1

Experts had a median self-assessment of experience for this WoE assessment of 7 (ranging from 3 to 10, with 9 out 11 participants scoring ≥7) indicating most participants felt confident supporting this exercise. In general, the feedback on the process was positive with average scores of 7.4 and 7.1 for ease of use of the assessment and the guidance supporting it.

It was noteworthy that experts invested variable amounts of time in the assessment, ranging from 1.5 – 6 h. Many experts highlighted they tried to minimise time in the assessment (as directed in the spreadsheet) and had they invested more time; their assessment might have changed. Their feedback on the ease of the assessment and time investment was broadly correlated to the level of experience

self-assessment (with those identifying as more experienced, spending less time citing familiarity with the evidence base).

Table 3 - Summary of feedback scores from participant on the process.

Feedback Topic	mean	sd	min	max
Participant self-rating of experience as it relates to the WoE exercise	6.9	1.9	3	10
Ease of use of WoE assessment structured process overall (1-10)	7.4	1.6	4	10
Ease of use of "Rating Evidence" tab (1-10)	7.1	1.9	4	10
Time spent on WoE assessment (hours)	3.4	1.6	1.5	6

Figure 2 and

Table 4 show the output of the overall WoE assessment in this case study. This figure shows that the weight of evidence supported the outcome to “refute” the statement/assumption (i.e. that if this was a real WoE assessment on this topic, the advice would be to refute the use of a 26 km EDR for porpoises in response to unabated pile driving of monopiles). This is determined by the result that all values from the assessment were negative with mean WoE values of -0.65 (corresponding to a confident refutation of the statement being assessed – see Table 1) across all participants.

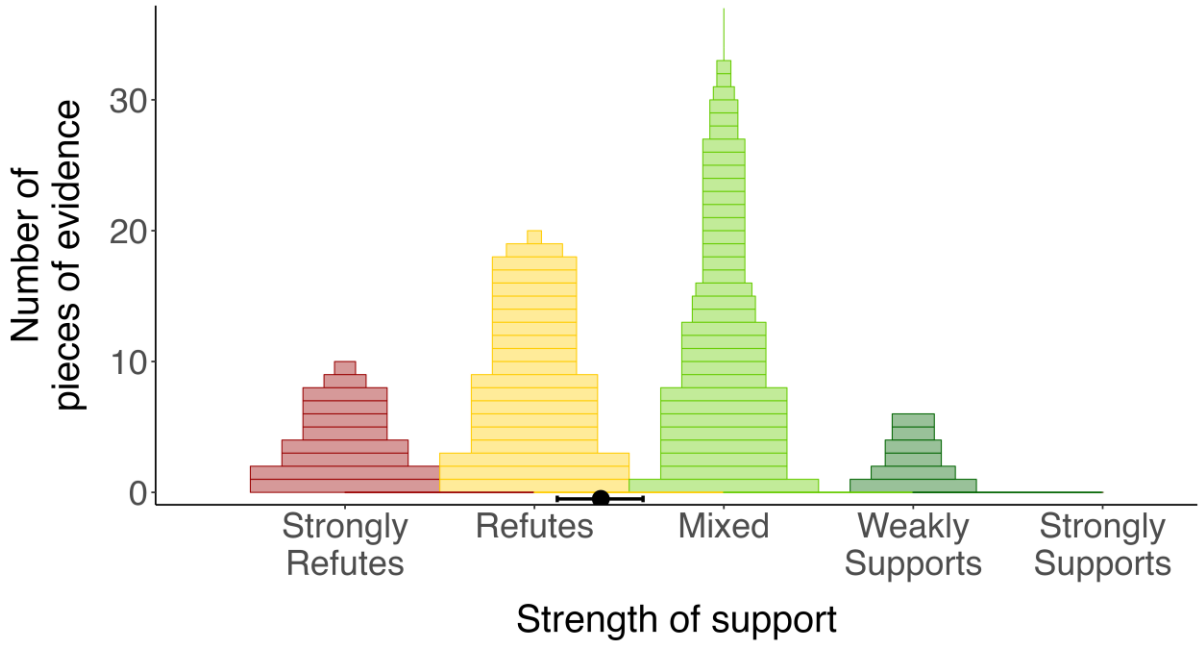

Figure 2 - Output from the WoE assessment for all participants. Coloured blocks show the weights of each participant-evidence piece in the 5 ‘strength of support’ groups which provides a representation of the balance of weights across this spectrum. The weighted average strength

of support effectively shows where the central point of balance lies in the overall support of evidence for the assumption (black point with bootstrapped 95% Confidence Intervals).

Table 4 - Summary of the mean WoE results (for data from Figure 2-5). The interpretation key for scoring is shown below.

Group	Lower 95% CI	Mean	Upper 95% CI
All participants	-0.88	-0.65	-0.43
Experience ≥7	-0.90	-0.64	-0.38
Government+SNCB+NGO	-0.83	-0.53	-0.25
Research+Industry+EIA	-1.19	-0.82	-0.50

We also explored the scoring further to understand if this case study in developing an Evidence Bridge process output would be markedly different if carried out based on the level of (self-assessed) experience of the participants. Additionally, we re-analysed the data using a subset of participants to understand the extent to which our results were biased by their current role.

The results indicated that the outputs would have been very similar if only higher experience individuals participated or focused groups from conservation/management groups as opposed to selecting researchers, practitioners etc. (Figure 3, Figure 4 and

Table 4). No comparative statistical tests were used to assess this, but given the strong overlap in all 95% confidence intervals (overall and when split by group) indicates no significant difference. In all cases the weight of evidence was on "refute" the statement/assumption (i.e. that if this was a real WoE assessment on this topic, the advice would be to refute the use of a 26 km EDR for porpoises in response to unabated pile driving of monopiles). This is because all values being negative with mean WoE values ranging between -0.53 ('*Government+SNCB+NGO*') and -0.82 ('*Research+Industry+EIA*') (both with narrow confidence intervals) corresponding to a confident refutation of the statement being assessed (

Table 4). It was noteworthy that there was mild divergence between different groupings. It is challenging to determine what exactly is driving this difference and we note the sample sizes for the members of these putative groupings. This could be explored further in future studies.

The purpose of an Evidence Bridge process to support decision making is that it provides a clear headline statement of the current state of knowledge. 0 provides an indicative output of this Evidence Bridge process – providing a clear process and headline position on the topic assessed (albeit from a trial run of the process).

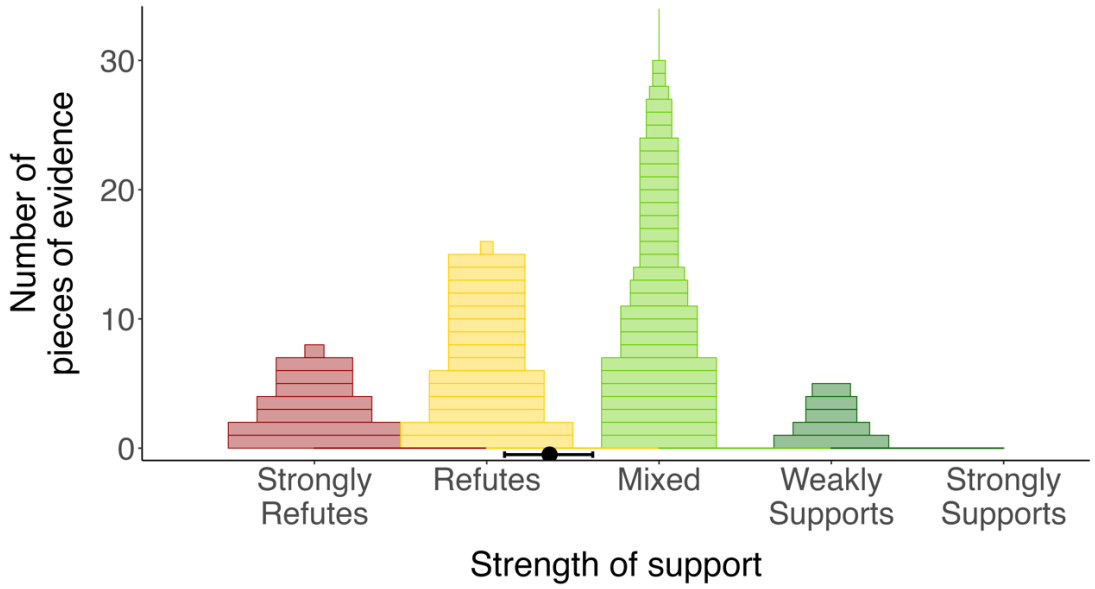

Figure 3 – Results of WoE assessment using only data from participants where they self-assessed their relevant experience to be >7 (on a 1-10 scale, where 1 is low, 10 is high). The weighted average strength of support effectively shows where the central point of balance lies in the overall support of evidence for the assumption (black point with bootstrapped 95% Confidence Intervals).

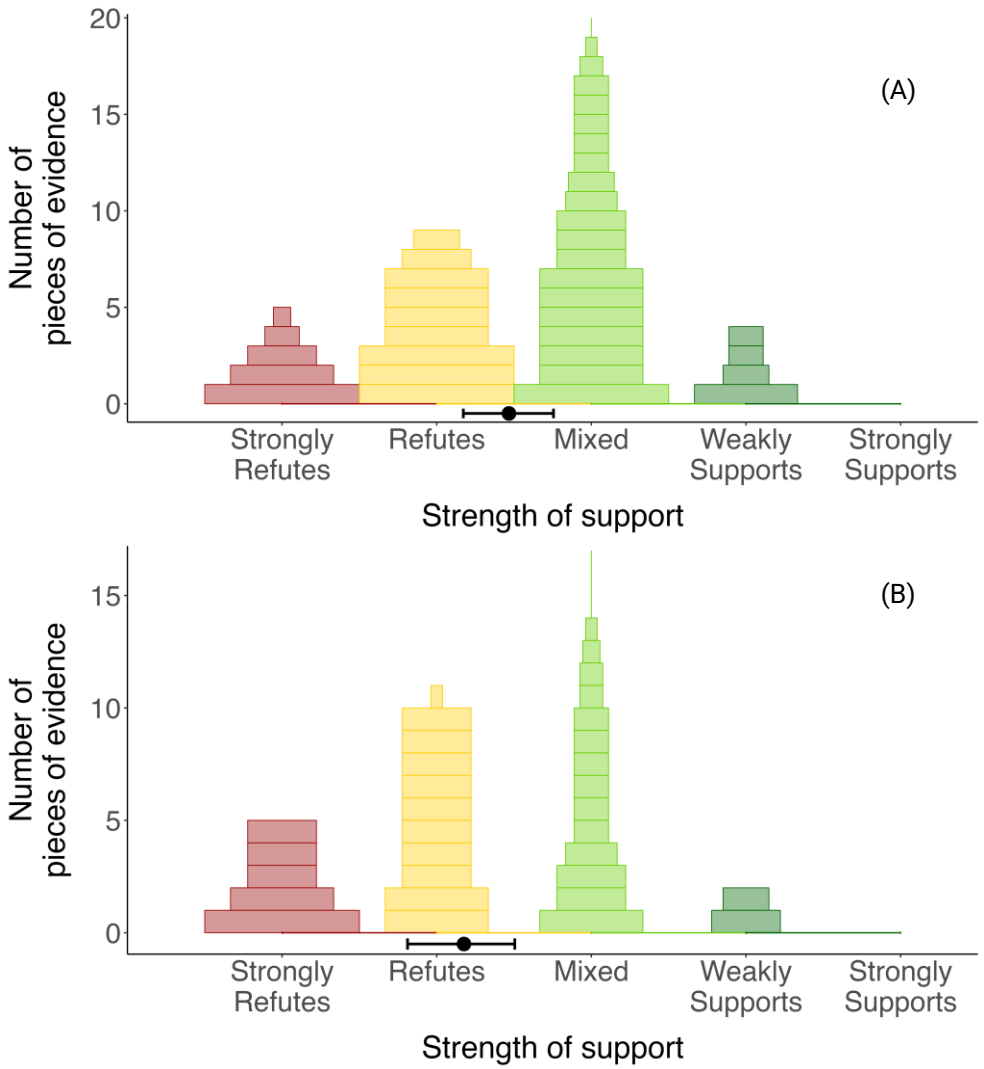

Figure 4 - Results of the WoE assessment using data from participants who (A) represented government, SNCBs or environmental NGOs and (B) those identified as researchers/consultants, EIA practitioners or industry. The weighted average strength of support effectively shows where the central point of balance lies in the overall support of evidence for the assumption (black point with bootstrapped 95% Confidence Intervals).

4. Discussion

This work package has designed and executed an Evidence Bridge process, building on the work of Christie, et al (2023). The assessment has been successful in generating meaningful assessments of the state of knowledge to a subset of the available evidence.

During the stakeholder engagement process, positive feedback was gathered in support of this kind of process supporting decision-making. One of the main pieces of feedback that arose around the need for a clear, transparent process with a clear headline. As such, this was a focus of the study – i.e. to generate a simple headline statement on support (or lack thereof) for a given statement of assumption which provides a clear steer to decision makers about the evidence can be interpreted to inform specific decisions. A draft output (based on this trial assessment) is included in Appendix 2: Example output

from WoE assessment*. This demonstrates how the process can synthesise evidence down to a simple position to guide decision makers.

We note the papers selected for inclusion in this evidence assessment were selected to intentionally draw across a range of study types (e.g. survey methods, monitoring pin and monopiles and analysis techniques) and did not represent all available information on the topic. Therefore, we cannot rule out that different evidence or the use of a summary of the evidence base might change the outcome of this specific case study. As noted above, the goal was to develop a replicable process to deliver evidence bridges across a range of topics and taxa, not to specifically assess the evidence base on porpoises and EDRs. Some participants suggested that some kind of synthesis was needed before a WoE assessment could be done, and that this might streamline the process and time commitment required. This is important because many participants struggled to make time for this assessment but contributed on a voluntary basis. They highlighted there was a lot of evidence to review, and variable amounts of time committed to the assessment. Many had to decline due to a lack of time available to contribute. This highlights a bottleneck in the general process of the assessment of scientific evidence to inform decision making and illustrates why it hasn't been done effectively to date. We caution against this approach as it is challenging to collate or synthesise evidence without bias. Of course, removing bias is challenging, because it is inherent in all data and all human judgments. We recommend that co-development of a suitable evidence approach which minimises bias but increases user confidence in the process (i.e. striking a balance between acknowledging bias and develops comfort in use of such approaches). Another alternative is to continue with the structure as shown here, but with the participation of experts funded to assess evidence. This highlights a need for dedicated resources to cover expenses and allow experts to participate and commit sufficient time to such assessments.

4.1. Benefits of the Evidence Bridge approach in 'Closing the Loop'

This project has demonstrated (with refinements) that this process can help support decision-makers by assessing and weighing the evidence in support or against a statement. Additionally, this kind of approach can support the targeted direction of new projects to further add to the evidence base (e.g. in instances where the evidence base points to 'mixed/neutral' positions, or where a paucity of data limits a clear position being established). In all cases it would be beneficial if such processes also help indicate the reasons for support or refutation or mixed/neutral positions – this would aid transparency and likely increase uptake. These and other elements described above and below can be considered to improve the utility of such approaches.

This ties into the broader process of how the evidence base can be collated (e.g. using processes such as the Offshore Wind Evidence and Knowledge Hub (OWEKH)[7]). The weight of evidence assessed to help improve support for decision makers now – and more targeted science delivery, on meaningful timescales to affect change (e.g. helping to deliver the strategic roadmap goals of the Offshore Wind Industry Council Pathways to Growth).

Additionally, because this kind of process requires engagement with stakeholders (evidence bridges facilitate an improved understanding of needs of practitioners, policy and decision-makers) this can

[7] https://owekh.com/home

also stimulate more targeted ideas from researchers who are generating new evidence and testing hypotheses - all of which can support an improved and streamlined use of the evidence base. Further, this approach can facilitate a better understanding of the implications of research outcomes with close ties to how new evidence can be applied.

This kind of evidence bridge process, if deemed successful and useful, it can be replicated to form an annual process, which can result in regular reviews of evidence in critical areas – which in turn can lead to a better consensus on common approaches to assessment methods and the challenges of uncertainty and transferability. Ideally evidence bridges can lead to the co-production of guidance (i.e. across SNCBs) whereby there is coordinated use of the evidence base.

Finally, this kind of approach fits into the current structure within the UK whereby needs are assessed, funding sourced and the outputs disseminated to the community (e.g. emulating elements of ORJIP, ScotMER and some elements of the Offshore Wind Environmental Evidence Register) (Figure 5).

Critically, the evidence bridge step ensures the uptake of evidence into decision making which can help streamline consent decisions (e.g. by independent advice being delivered to support case workers). Additionally, by providing a means by which the evidence base can be critically assessed, this can in turn ensure that the most critical evidence gaps (i.e. Needs) can be identified and prioritised for funding. This missing link in the funding-evidence cycle can ensure an enhanced and focused funding cycle, support decision makers and streamline evidence-based decision making.

Figure 5 - An example of closing the loop. The four elements are displayed covering "Needs" (i.e. evidence gaps that impede progress), "Funding" (i.e. where research or evidence bridge processes are funded), "Circulate" (i.e. where outputs are communicated in meaningful terms to aid stakeholders) and "Evidence Bridges" (i.e. a dedicate process helping ensure the uptake of research for stakeholders (and informing the next set of key needs, for which funding can be sought).

5. Conclusions

We have developed and tested a process that appears fit for purpose to deliver Evidence Bridges, aiding decision makers and closing the loop between the generation of evidence and the uptake of it.

We have demonstrated how per evidence gaps can be addressed with this kind of dedicated and focused process – which addresses targeted questions or statements and provides, as an output, clear and decisive take-home messages to aid decision makers. This kind of process likely works best with targeted statements or questions- this narrow focus means it is best suited to underpin key elements of position statements. A benefit of this approach is that it can be repeated or expanded relatively easily (e.g. asking participants to review and new paper or report and re-running an existing analysis).

In situations where a broader understanding of the state of knowledge is required broader reviews can help provide a narrative on a topic area, potentially helping identify where to collect new data (using targeted studies), or carry out meta-analyses (if extensive datasets exist. e.g. to estimate EDRs in porpoises). This study has generated a transparent, repeatable and generalised process with a marine mammal case study – but can be utilised (with or without refinement) on a wide range of taxa or topic areas. This study provides templates to achieve this.

Critically this process requires dedicated funding and resourcing as time is a critical limitation. However, the investment required to build evidence bridges in this manner is very modest to the investment in collection of new evidence, which historically, has had no mechanism to incorporate this into decision-making.

5.1. Recommendations

Following on from this trial, we recommend the following:

- The Evidence Bridge process is further developed and refined to ensure confidence and buy-in from stakeholders. This development could include codifying approaches for the collation and synthesis of evidence and updating outputs to ensure the outputs are appropriate for use by decision makers or their advisors.
- The process detailed here is tested on another taxa (e.g. birds) and/or different issues to confirm its broader utility and feasibility.
- Given that time and resourcing have been identified as the biggest barrier to success, it is prudent that investment is set aside to fully resource an Evidence Bridge process to support decision makers and research funding mechanisms over the next decade.
- This continued development should include dedicated training to develop a cadre of experts to assess the evidence. By training a cadre of experts for each taxon (e.g. a marine mammal group, an ornithology group etc), it is possible draw down on a smaller group of experts for any specific topic within taxonomic groups.
- A logical avenue to advance this topic would be via engagement with the Offshore Wind Evidence and Change (OWEC), Offshore Wind Evidence Knowledge Hub and Offshore Wind Industry Council (OWIC) roadmaps and the many industry stakeholder groups and programmes.

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Appendix 1: Evidence Bridge template

The CTL_EvidenceSheet_FINAL can be downloaded here. This is the file provided to participants in this study. It requires light editing before it can be used in another Evidence Bridge process.

Below provides a summary of the instructions provided to participants in the WoE assessment.

1.1 Introduction

Research project: Developing an "Evidence Bridge" process for use in management and conservation decision-making (Work Package 4 of the "Closing the Loop" project). This research project is being conducted by Cormac Booth, Carol Sparling and Gordon Hastie. The study examines how to weigh up different sources of evidence to make informed decisions in conservation or management setting. The objective is to pilot test an evidence assessment approach to rating different pieces of evidence that support or refute an assumption.

This exercise focuses on a specific assumption as a case study for the development and improvement of the evidence assessment approach.

You have been invited to participate as someone who provides evidence (e.g. scientist) or assesses evidence (e.g. decision maker)

In this questionnaire, you are asked to consider an assumption/statement and then providing ratings of different aspects of seven pieces of evidence that may support or refute that statement. The statement or assumption being considered is: *"The evidence supports that the Effective Deterrence Range for harbour porpoises in response to unabated monopile driving is 26 km"*.

Please note we have selected seven pieces of evidence to minimise the level of effort as the primary focus of this work is to develop this process. In reality there many papers and reports that could support this exercise but our goal is to test the process more than to review all evidence on this topic.

You will be asked to provide ratings (on a four point scale) for:

1. How well each piece of evidence supports or refutes the assumption,
2. The source reliability of evidence (i.e., how much can the source be trusted?),
3. The information reliability of evidence (i.e., how much can the information provided by the evidence be trusted?), and,
4. The relevance of the evidence (i.e., does this evidence apply to the assumption?).

These terms are defined in more depth in the spreadsheet within the questionnaire and standardised guidance is provided on how to assess them. We anticipate the assessment will takes from 1-2h, but could take more depending on familiarity with the evidence base. There is an opportunity to give open-ended feedback on the approach.

1.2 EDR definitions

As described by Brown et al. (2023), while all studies of porpoise responses to piling report on the spatial extent of responses, it is very uncommon for such studies to estimate the EDR. Therefore, it is challenging to determine if reported response ranges are under- or over-estimating response ranges in terms of the average habitat loss per individual.

Where possible, we consider the results of the reviewed literature in the context of the definition of an EDR as developed from a deterrence function (response vs distance), as per Tougaard et al. (2013) and analogous to the Effective Response Range (ERR) described in Tyack and Thomas (2019). This provides a measure of the average temporary habitat loss per individual, and accounts for individual differences in responses of animals at a given range from the source, with some not responding at closer ranges (losing less habitat) and some responding at larger ranges (losing more habitat). The EDR is a threshold distance: beyond this distance the number of animals responding to the disturbance equals the number of animals not responding within that distance (Figure 6).

This means an EDR does not correspond to the maximum spatial extent of disturbance or the maximum observed range of effect.

The aforementioned EDR metric is preferred to alternative metrics such as D50 (the distance at which there is a 50% probability of response), which fails to account for the exponential increase in size of disturbed area with range from source and therefore underestimates the number of animals responding and the average habitat loss (Tyack and Thomas 2019).

The EDR is a threshold distance: beyond this distance the number of animals responding to the disturbance (represented by the red triangle) equals the number of animals not responding within that distance (green triangle).

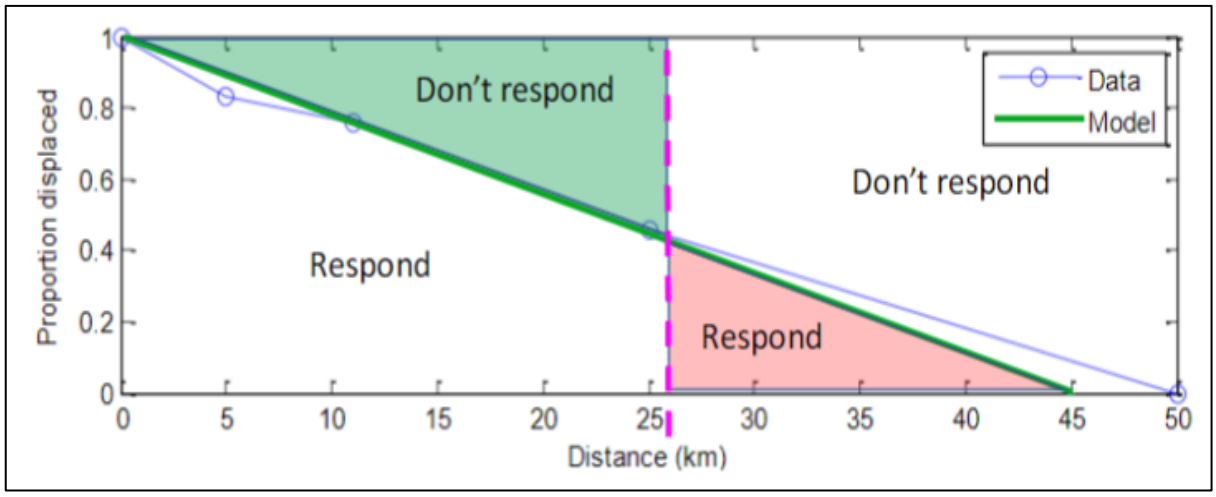

Figure 6. A modification of Figure 7 from Tougaard et al. (2013) to illustrate how the EDR (purple dashed line at 26 km) relates to a deterrence function. By assuming a uniform density of animals and that the deterrence function is symmetrical in all directions, the proportion displaced (or probability of response) is used to estimate the cumulative number of animals responding and not responding with increasing range from source.

1.3 Guidance on Source Reliability, Information Reliability and Relevance scoring

1.3.1 Scoring Categories:

Evidence Criteria	Categories				
Strength of Support	**Strongly refutes**	**Refutes**	**Mixed Support**	**Supports**	**Strongly supports**
	Evidence strongly refutes the assumption.	Evidence somewhat refutes the assumption.	Evidence does not support or refute the assumption, OR both supports AND refutes it (to an approximately equal extent).	Evidence somewhat supports the assumption.	Evidence strongly supports the assumption.

Source reliability (S)	**None**	**Low**	**Moderate**	**High**
Overall?	Not trustworthy source.	Concerns over credibility.	Evidence is probably trustworthy, but some concerns that reduce confidence as a reliable source.	The source is very reliable.

Information reliability (I)	**None**	**Low**	**Moderate**	**High**
	The information provided has been collected or derived in a way that is misleading, unreliable and invalid and cannot be relied upon.	The information provided has been collected or derived in a way that is not very reliable or valid - i.e. there are several areas of concern.	The information provided has been collected or derived in a way that is generally reliable and valid - but there are some areas that reduce confidence.	The information provided has been collected or derived in a way that is highly reliable and valid - i.e. no major concerns.

Relevance (R)	None	Low	Moderate	High
	Evidence has no relevance to the assumption - the information has no use.	Evidence has limited relevance to the assumption. Several small additional assumptions or a few large assumptions are required to relate the evidence to the assumption.	Evidence has some relevance to the assumption but a few small additional assumptions are required to relate the evidence to the assumption.	Evidence is highly relevant to the assumption and no additional assumptions are required to relate the evidence to assumption.

1.3.2 Potential considerations for the three indices (S x I x R):

Potential considerations for Source Reliability

o How much can the authors of the piece of evidence be trusted? Are they respected and trusted by others? Do they have a track record of providing reliable information?

o Is the source open and transparent in their reporting or communication of information? Is there linguistic uncertainty?

o How likely is the source to have overestimated success or underestimated failure or negative impacts?

o Is the source of information formally peer reviewed or from a reliable source?

o How likely is the source to have overestimated their expertise or ability as an expert (i.e., suffers from the Dunning-Kruger Effect)?

• How likely is the source to only provide evidence that supports their own original viewpoint or opinions (e.g., Confirmation bias)?

Potential consideration for Information Reliability

• How uncertain are the observations, data, or conclusions?

• Is the information direct or indirect (first-hand or second-hand)? Has the information been previously verified or checked and scrutinised?

• Are the approaches, measures, or methods used to generate the information valid, appropriate, and trustworthy? If causation is implied, is it supported by the methodology or approach used?

• Has the information been shown to be replicable in space or time or repeatable (for uncontrolled experiments (e.g. observational studies) as much as is reasonable)?

• Is the information triangulated or from multiple complementary approaches or sources?

Potential considerations for Relevance

• Is the information derived from a similar context to the one being considered? If a different context, is there evidence indicating this affects the relevance?

• Is the evidence up-to-date or out-of-date and no longer applies?

• Does this make the evidence transferable or applicable to the assumption?

• If the assumption is about an action, is the implementation, duration, and scale of that action similar to the action of interest?

• Are the metrics, measures, or outcomes presented in the information relevant to the assumption?

Appendix 2: Example output from WoE assessment*

Statement for which the evidence based is being assessed: "The evidence supports that the Effective Deterrence Range for harbour porpoises in response to unabated monopile driving is 26 km"

Weight of Evidence: The figure below presents the WoE assessment using the evidence base (below) to take a position on the assumption/statement (above):

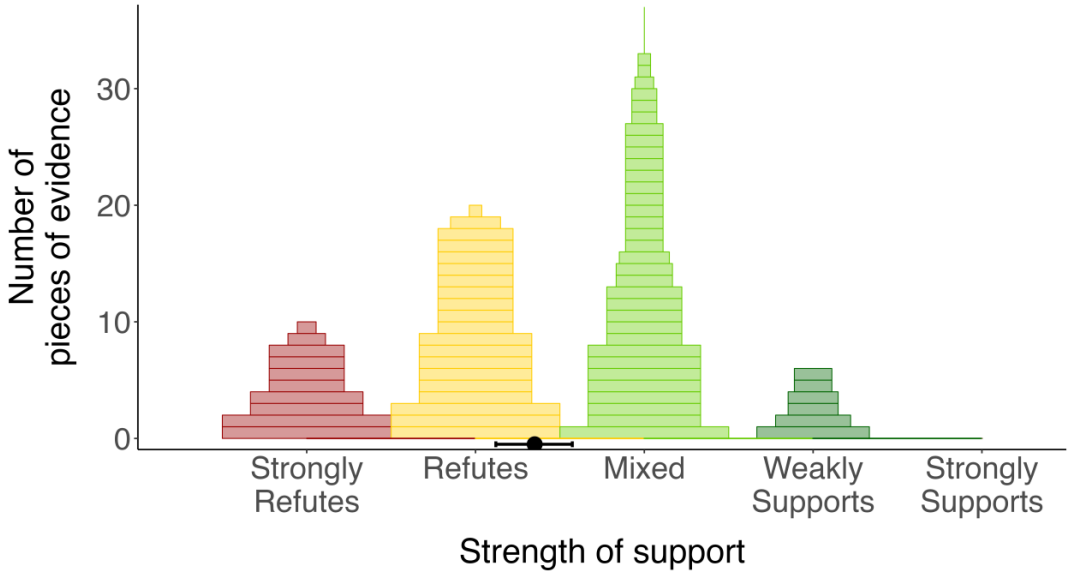

Figure 7 – Distribution of evidence from this WoE assessment. Each stack represents a 2D representation of where each weight of evidence (determined for each participant-evidence combination) fits on this spectrum (from 'strongly refutes' to 'strongly supports'). The black dot and line indicate the mean and 95% confidence intervals around the weight of evidence.

Table 5 - Summary of the WoE assessment. A key is shown overleaf to guide the interpretation of these scores.

Group	Lower 95% CI	Mean	Upper 95% CI
Scores	-0.88	-0.65	-0.43

Summary: This exercise has determined that the assessed evidence does not support (i.e. confidently refutes) the adoption of a 26 km EDR for harbour porpoises during unabated monopile installation.

This is due to the mean value of -0.65 (with confidence intervals between -0.88 and -0.43 providing a strong likelihood that there is certainty around the mean assessment).

Mean/CI score	Interpretation
-2 to -1.2	Strongly refute statement being assessed
-1.2 to -0.4	Refute statement being assessed
-0.4 to +0.4	Mixed / Neutral
+0.4 to + 1.2	Support statement being assessed
+1.2 to +2	Strong support statement being assessed

1.1.1 Evidence Base:

The following papers were considered in this WoE assessment:

- Benhemma-Le Gall, A., Graham, I. M., Merchant, N. D., & Thompson, P. M. (2021). Broad-scale responses of harbor porpoises to pile-driving and vessel activities during offshore windfarm construction. Frontiers in Marine Science, 8, 664724
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N.B. The above is an indicative example of an Evidence Bridge process output, and may not be considered a full assessment of the statement/assumption being challenged.

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