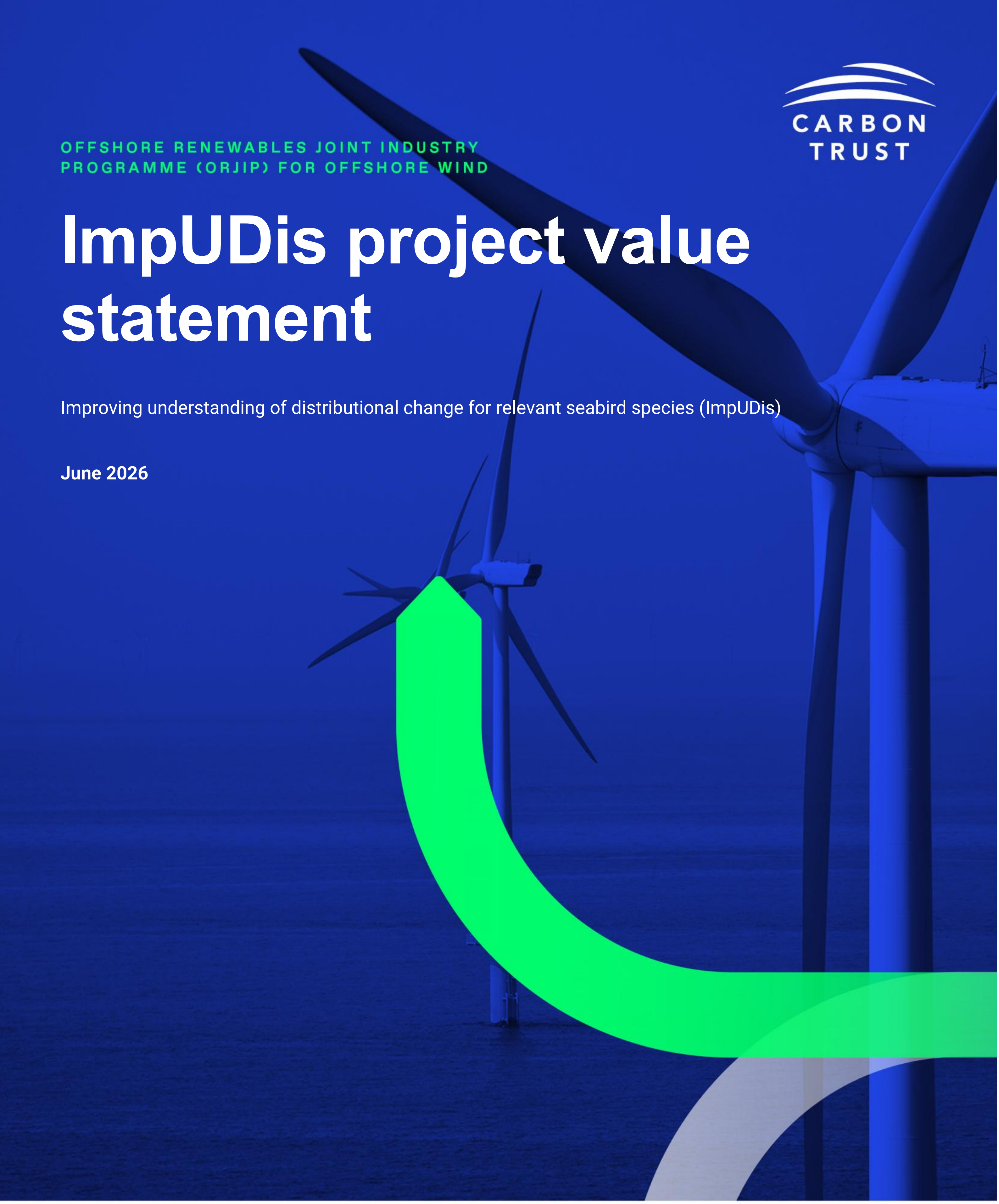

OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

ImpUDis project value statement

Improving understanding of distributional change for relevant seabird species (ImpUDis)

June 2026

Contents

Why ImpUDis matters

Offshore wind is central to the UK's transition to clean energy. But consenting new developments depends on assessing their potential impacts on protected seabird populations — and for two decades, assessments have been hampered by significant uncertainty about how far seabirds actually redistribute in response to a wind farm (e.g., London Array Phase 2 and East Anglia One North for Red-throated Diver). When regulators cannot be confident in the underlying displacement rate, they must take the precautionary route, which increases both the cost and the consenting risk of new projects.

ImpUDis was established by **ORJIP Offshore Wind** to address this uncertainty head-on. Over four work packages, the project delivered: a review of the available evidence base; a formal, reproducible guidance framework for estimating redistribution; a real-world test of that framework using data from eight UK offshore wind farms; and a stakeholder workshop to validate methods and findings with regulators, industry and conservation bodies.

This briefing is a focused summary of the usefulness of what the project has produced, with some focus on the outputs from independent reviews of WP1 and WP2/WP3. The full technical findings sit in the main final report; the purpose here is to set out, in balanced terms, what ImpUDis delivers, where it can be put to work, what value it is expected to generate, and what has to happen next for that value to be realised in practice.

CORE FINDING

ImpUDis shows that displacement is real and measurable with a modern, reproducible framework — but realising the full value depends as much on a sector-wide data-infrastructure effort as on any further methodological advance.

1. The consenting problem ImpUDis addresses

Seabirds can respond to offshore wind farms (OWFs) in four broad ways: they may be displaced, attracted, treat the structures as a barrier, or show no change at all. Each of these responses can, in principle, carry through into population-level consequences for species that are protected under the Habitats Regulations. For Environmental Impact Assessments (EIAs) and particularly for Special Protection Areas, regulators must determine whether there will be an Adverse Effect on Integrity (AEoI). Where that test cannot be met, mitigation or compensation is required — and in some cases consent itself is put at risk.

The difficulty is that the evidence base is genuinely variable. Some sites and species show clear displacement; others show attraction; others show no detectable change. Published displacement rates for the same species can vary enormously. In the absence of a settled, site-informed figure, the rational regulatory response is to apply a precautionary range — and for many species and sites, that precautionary range is wide.

The cost of that precaution does not sit only with industry. Over-conservative displacement assumptions can trigger mitigation or compensation obligations that may not be ecologically necessary; they can delay consenting decisions; and they can divert effort away from the impacts that matter most. The goal of ImpUDis was not to argue for or against displacement as a phenomenon, but to build the tools and evidence that allow each case to be assessed on its own merits, with quantified uncertainty.

2. What ImpUDis delivers

The project produced four inter-connected outputs. Each is useful on its own; together they form a coherent advance on current practice.

2.1. A consolidated evidence base (WP1)

WP1 assembled and reviewed 76 studies from 35 European offshore wind farms, spanning 1998 to 2024 and covering seven distinct survey platform types. Around 41% of reviewed studies reported statistically significant displacement or attraction, with strong tendencies towards avoidance in auks, gannets and divers, and more variable responses in kittiwakes. The review is valuable in its own right: it is the most current consolidated reference on OWF seabird response studies, and it has already exposed a consistent data-quality problem that a large proportion of existing monitoring data cannot be used for robust redistribution analysis.

2.2. A standardised analytical framework (WP2)

WP2 translated the evidence base into a formal guidance document for estimating seabird redistribution. It specifies what a defensible analysis must contain: a Before-After-Gradient (BAG) study design; explicit treatment of survey effort; a tidy, machine-readable data format with documented metadata; and a reproducible modelling workflow that produces estimates with quantified uncertainty. The framework is deliberately non-prescriptive on the choice of model — it mandates essential features (effort correction, spatial autocorrelation, uncertainty estimation) rather than a single model family.

2.3. A practical test at scale (WP3)

WP3 applied the framework to real monitoring data from eight UK offshore wind farms, fitting approximately 54 redistribution models across species and sites. The analysis confirmed the framework is workable at scale and produced concrete estimates of redistribution — including clear evidence of gannet and puffin avoidance at Beatrice, kittiwake attraction at Beatrice and Robin Rigg, and a range of site-specific findings across auks and divers. Equally importantly, WP3 clarified where the framework delivers most value (functional distance and spatial models) and where simpler approaches are sufficient.

2.4. Cross-sector validation (WP4)

WP4 brought together approximately 20 stakeholders from regulators, statutory nature conservation bodies, NGOs, developers and academic institutions. The workshop validated the analytical approach and crystallised three priorities: methods should define essential features rather than prescribe a single model; outputs must feed directly into existing assessment tools; and the sector needs a coordinated data-infrastructure effort to sustain progress.

3. Where the framework can be applied today

The WP2 guidance is designed to be directly compatible with the existing UK consenting framework. There are three practical pathways by which ImpUDis outputs can be integrated into assessments, each with a different balance of effort and expected value.

Pathway	Approach	What it replaces / improves on	Effort
1	Displacement matrix input	Insert the simple redistribution estimate, with confidence limits, directly into the existing displacement matrix methodology used in EIAs.	Low
2	Gradient-based mortality	Use the distance-functional output to distribute mortality spatially — replacing a single assumed rate with a distance-varying profile.	Medium
3	Individual-based models	Feed the density-surface output into individual-based models (e.g. SeabORD, DisNBS) as input layers, enabling site-specific counterfactual scenarios.	Higher

Pathway 1 is the most immediate and requires no change to current assessment tooling — it simply replaces an assumed literature rate with an empirically derived one. Pathway 2 extends the matrix approach with a spatial dimension, and pathway 3 integrates ImpUDis outputs into the most sophisticated assessment tools available. None of the three pathways is exclusive: the same project can begin with pathway 1 and progress to pathway 3 as data and resources allow.

4. Expected benefits of adoption

Adopting the ImpUDis framework in future offshore wind assessments is expected to deliver tangible benefits across three dimensions. The benefits are real but should be understood as contingent — they depend on the availability of analogous datasets and on a level of data standardisation that the sector does not yet systematically have.

4.1. Reduced uncertainty in displacement estimates

Current assessments typically rely on a single precautionary displacement rate drawn from literature ranges. The WP2 framework produces a site-informed estimate with quantified uncertainty and, where the data allow, a spatial gradient of effect. Replacing a literature-range assumption with a site-informed estimate — with confidence intervals — narrows the statistical envelope that assessments must work within, and makes the basis for any remaining precaution explicit.

4.2. More proportionate EIA outcomes

Where empirical displacement proves lower than precautionary assumptions suggest, more proportionate Environmental Impact Assessment conclusions become possible, reducing the likelihood of concluding Adverse Effects on Integrity on the basis of uncertainty alone. Conversely, where displacement proves higher, the framework provides the evidence to support that conclusion robustly. In both directions, the assessment is grounded in site-specific evidence rather than generic worst-case assumptions.

4.3. Cumulative learning across sites

The framework is explicitly reproducible: results can be compared directly across sites and species, and revisited as new data become available. Over time, this creates a genuine evidence base that grows with each new development, rather than each project starting from the same precautionary baseline.

THE SHIFT IN PRACTICE

From a single assumed rate applied to all sites — to a site-informed estimate, with quantified uncertainty, and a spatial gradient of effect.

5. Independent review of the work packages

Two of the project's core technical outputs were subjected to independent external review. The WP1 literature and data review was assessed by Edgewise Environmental, and the WP3 application of the framework was peer-reviewed by Dr Evan Adams of the Biodiversity Research Institute. Both were conducted in the manner of formal scientific manuscript review. Taken together, they provide an external check on whether the project delivers the value this briefing describes — and, on balance, they affirm that it does, while identifying refinements that bear directly on how that value is realised in practice. In the context of this work, the review of WP2 was performed within the review for WP3 as much of the WP2 material was used to inform the review of WP3. Thus, we take the WP3 review here also as a review of the WP2 guidance and analytical approach.

5.1. Review of the evidence base (WP1)

Edgewise Environmental judged the WP1 review to be exceptionally well thought out and clearly written and framed its recommendations explicitly as refinements to strengthen rigour rather than challenges to the substance of the work. On the treatment of attraction and habitat selection, the review suggested noting the role of the "reef effect" over time, since benthic colonisation and the prey it attracts take time to establish and early post-construction surveys may therefore record indifference or displacement before any localised attraction develops. It recommended formally stating the protection status of priority to reinforce the regulatory context.

The review of WP1 reinforced the value case set out in this briefing. It highlighted a turbine-generation bias — the heavily cited early projects such as Horns Rev and Nysted used small, tightly spaced turbines, whereas modern and future UK assets use far larger, widely spaced wind farm designs — and cautioned that pooling historical and modern data without standardising for turbine capacity or layout density risks masking contemporary displacement rates. It flagged the structural mismatch between telemetry data (skewed toward breeding adults under central-place foraging constraints) and digital aerial survey data (which captures the wider population, including immatures and non-breeders), and the analytical risk created by historical studies using narrow survey buffers that may fall entirely within the impact zone. It recommended that jurisdictional fishery status be treated as a high-priority covariate, and that a clear caveat be added against over-extrapolating Southern North Sea displacement rates to the Irish Sea, Celtic Sea or deeper Scottish waters. Each of these observations strengthens the briefing's existing position that results are site-specific and that historical data carry structural limits — and underlines why the data-standardisation actions set out in Section 6 are central to realising the project's value.

Comments from the WP1 review were not formally included into the WP1 output itself as there were no substantive changes that would alter any of the messaging already in the initial report. The full review of WP1 by Edgewise Environmental is found in Appendix 1 of this report.

5.2. Review of the practical test (WP3)

Dr Evan Adams of the Biodiversity Research Institute reviewed the WP3 report as a peer-reviewed scientific manuscript would be assessed. He characterised it as a useful application of statistical methods that builds on recent syntheses of the topic and, importantly, directly supports the recommendation that original datasets be aggregated and analysed rather than relying on summary literature — the same conclusion this briefing reaches. He found the evaluation of the WP2 research questions particularly helpful and the general results section well constructed, confirming that the framework is workable and informative at scale, which is the central claim of Section 2.3.

The review's main observations were that the report relied too heavily on the code repository for methodological detail and should be made to stand on its own; that some claims were not fully supported by the analysis presented; and that only a small subset of relevant spatial methods was assessed, with established approaches such as MRSea and INLA excluded largely on logistical grounds rather than analytical ones. It recommended that true spatial models (for example conditional autoregressive or Matérn-covariance approaches) be considered and compared directly, that more detail be given on non-linear effects and on model validation, and that the definition of "pooling" be clarified. It also noted that the discussion would benefit from a closing section synthesising the findings into clear recommendations, and that the treatment of Bayesian and frequentist approaches was inaccurate in places and should be revisited.

These comments were taken on board in finalising the outputs: the report was revised to stand on its own without reliance on the code repository, key claims were more fully substantiated, the range of spatial modelling approaches considered was broadened, and the discussion was extended to include a clearer synthesis and forward recommendations.

The full review of WP3 by the Biodiversity Research Institute is found in Appendix 2 of this report.

5.3. Summary

Two independent reviewers, approaching the work from different vantage points — an environmental consultancy and an academic research institute — reached compatible conclusions: the project's outputs are substantive, defensible and genuinely useful, and the most material improvements concern data standardisation, methodological breadth and transparent reporting. This is the same message the project reaches in the sections that follow, and it lends external weight to the briefing's central argument that the methodology is sound and the data infrastructure is the binding constraint.

INDEPENDENT VERDICT

Both external reviews affirm the value of the work: the evidence base is fit for client and stakeholder scrutiny, and the framework is workable at scale. The recommended improvements concern data standardisation, methodological breadth and transparent reporting — reinforcing the project's core conclusion that the methodology is ready and the data infrastructure is the bottleneck.

6. What is required for the value to be realised

The central caveat of the project, and the point most emphasised across both the WP3 analysis and the WP4 workshop, is that methodological advances alone cannot overcome fundamental constraints in the underlying data. A very large proportion of potentially relevant monitoring data could not be used in WP3 because of missing effort information, inconsistent formats, poor metadata, ambiguous species identification, or because the data existed only in aggregated form within PDF reports. Even where data could be used, substantial resources were required for bespoke cleaning before analysis could begin.

Four coordinated actions will translate the framework's potential into routine practice:

- **Mandatory retention and sharing of effort data.** Future post-consent monitoring surveys must retain and share survey tracks and sampled areas alongside observation records. Without effort data, robust redistribution modelling is not possible, and data stored only as summaries in reports cannot be used.
- **Consistent standards for monitoring data.** All monitoring datasets should adhere to consistent species coding conventions, machine-readable formats, defined spatial projections, and a comprehensive data dictionary. OWF footprints should be defined using actual turbine locations, not lease areas.
- **A centralised data repository.** A coordinated programme to collate existing pre- and post-construction survey data into a shared, accessible repository should be initiated as a priority. This would substantially reduce the data-recovery burden in future analyses and enable cumulative learning across sites.
- **Formal adoption as the expected standard.** Statutory bodies and industry should formally adopt the WP2 guidance as the expected approach for redistribution analyses, and regulators should consider embedding more prescriptive survey and metadata standards into consent conditions so that future monitoring data are fit for redistribution analysis from the outset.

These actions are individually tractable and collectively transformative. The marginal cost of retaining effort data from a survey that is already being conducted is small. The marginal cost of a consistent metadata standard is small. The marginal cost of a centralised repository, amortised across the sector's ongoing monitoring programmes, is small. The cumulative value — in reduced consenting risk, more proportionate assessments, and stronger conservation outcomes — is substantial.

7. Caveats and limitations

A balanced briefing must acknowledge what the framework does not yet do and where expectations should be calibrated carefully.

Results are site-specific. WP3 found that displacement patterns generally do not pool neatly across sites — the same species can show different responses at different developments. The framework therefore works best when analogous sites with suitable data are available; it is not a short-cut to a single generic displacement rate.

Some species remain data-limited. Priority species such as puffin and divers are represented substantially at only a small number of sites. Findings for these species should be treated as indicative rather than definitive until further analogous datasets become available.

Historical data has structural limits. Visual survey methods used in older datasets have detection-rate issues that prevent effective correction for detectability. The framework is most powerful when applied to modern digital aerial survey data.

Statistical power constrains what can be detected. Failure to detect redistribution in a given analysis does not imply absence of effect — it may reflect data volume, spatial coverage, or confounding from unmeasured environmental change. The framework is explicit about this and reports it as part of each analysis.

8. Conclusion

ImpUDis is a substantive advance on current practice in seabird displacement assessment. It provides a coherent, transparent and technically defensible framework; it has been tested on real data from eight UK offshore wind farms; and it has been validated across the sector through stakeholder engagement. The analytical methodology is fit for purpose, and the three integration pathways offer a clear route into the consenting process at whatever level of ambition a project or programme wishes to adopt.

At the same time, the project's most important conclusion is that the displacement problem is as much a data governance challenge as it is a statistical one. Without sustained investment in data retention, standardisation and sharing, each new analysis will continue to expend disproportionate effort on data recovery rather than ecological inference, and the full value of the methodology will remain out of reach.

The practical implication for the sector is straightforward. The methodology is ready. The data infrastructure is the bottleneck. Investment in that infrastructure — modest at the individual-project level, transformative in aggregate — is the single action that will convert ImpUDis from a technical achievement into a durable change in how offshore wind consenting works in practice.

Appendix 1: Work Package 1 — Literature and Data Review (Edgewise Environmental)

Overall, this report is exceptionally well thought out and clearly written.

Below are outlined considerations and recommendations that the paper could further benefit from to make sure it stands up to rigorous client and stakeholder scrutiny. Treat is as food for thought. The feedback below has been organized by section so it can easily be referenced.

Section 1

When discussing attraction or changes in habitat selection, it would be beneficial to explicitly note the role of the "reef effect" over time. If post-construction monitoring surveys are conducted too soon after construction, the localized ecosystem changes (benthic colonization attracting prey species) won't have established yet. Noting this helps explain why early post-construction windows might show indifference or displacement before turning into localized attraction.

The paper makes clear reference to distinct species throughout, however, formally name the protection status of priority species (e.g., Schedule 1, BoCC5 Red List, BoCCI4 Red List) would add valuable regulatory context and reinforce why reducing assessment uncertainty is so critical for these specific populations.

Section 2

The review clearly states that early projects like Horns Rev and Nysted are significantly overrepresented in the current literature. This section should explicitly state the structural and behavioral bias this introduces (which it does not currently include). Early wind farms utilized small turbines (2–3 MW) with tight spacing. Modern and future wind farms use significantly larger turbines (15 MW+) with vast spacing between sweeps. This trend will likely continue. Given behavioral responses can scale with turbine dimensions, tip speeds, and rotor heights, pooling historical data with modern data without standardizing for turbine capacity or layout density risks masking true contemporary displacement rates. Without this, calculated displacement rates will be unrepresentative of future UK asset builds.

Major digital aerial survey are increasingly shifting toward automated computer vision models for target detection and species identification. It would be progressive to briefly state if the modern literature (2022–2024) is beginning to report on the use of AI/automated image recognition software to process these datasets. While this won't change historical data, it introduces a subtle shift in modern detection probabilities and data turnaround times.

The paper could benefit from pointing out a structural mismatch between data streams that could bias population inferences. The text misses the regulatory "so what?" aspect. Telemetry data is heavily skewed toward breeding adults due to colony capture constraints, meaning these birds act under central-place foraging limitations. Digital aerial surveys capture the wider population snapshot, including non-breeders and immatures. Because immature birds have entirely different energetic constraints and potentially lower macro-avoidance thresholds than an adult protecting a clutch, over-relying on telemetry gradients could inadvertently ignore the demographic that drives long-term SPA conservation viability.

The discussion notes that older studies used narrow 2–4 km buffers, whereas contemporary guidelines require up to 10 km for sensitive species. The paper would benefit from this being framed as an analytical risk: if a species has a true displacement gradient out to 11–15 km, a historical study restricted to a 2 km buffer samples completely within the impact zone. This creates a false “flat density profile” across the study area that looks like indifference. The meta-analysis framework must explicitly account for study area scale as a structural constraint rather than a simple covariate.

Section 3

This may be out of scope but to assist the reader in understanding data-cleaning thresholds, it would be beneficial to add a brief sentence or two regarding how many tracked individuals or active tags were included / are required for a telemetry dataset to be considered statistically valid and powerful enough for inclusion in a common analytical framework.

Section 4

The text notes that availability bias must be accounted for in diving species, citing Dunn et al. (2024). However, availability bias is highly dynamic and shifts based on the covariates mentioned throughout. Applying a flat, static correction factor to old data lacking environmental metadata can introduce unquantified error into absolute abundance models. To prevent underestimating baseline densities, the pooled framework would benefit from flagging historical visual datasets that completely lack these associated dynamic environmental metadata layers.

Section 5

The distinction made regarding fishing restrictions between UK waters (open) and German/Belgian waters (closed) is a vital addition. Given certain species are highly opportunistic and closely track commercial vessels, an apparent “attraction” to a UK wind farm site could easily be an artifact of fishing vessels operating on the boundary rather than attraction to the turbine structures themselves. “Jurisdictional Fishery Status” must be flagged as a high-priority categorical covariate to avoid fundamentally skewing international meta-analysis results.

Section 6

Spatial Over-Extrapolation Caveat: Given the vast majority of historical data originates from the Southern North Sea, there needs to be a clear caveat regarding the ecological validity of extrapolating these exact displacement rates to upcoming leasing rounds in the Irish Sea, Celtic Sea, or deeper Scottish waters. This would add to a forward thinking conclusion.

Appendix 2: Work Package 3 — Report Review (Biodiversity Research Institute)

Review Scope

There are two components to this review: (1) this overall written assessment of WP03, and (2) tracked changes to the plan. The purpose of this written assessment is to provide a holistic assessment of the piece and address any significant issues with the organizational structure or analysis. The in-manuscript edits are intended to suggest improvements to the communication of ideas or comments specific to a line of text. Essentially, this report was generated in a similar manner to reviewing a scientific manuscript for a journal. I read the WP01 and WP02 reports but am not providing direct comments on those reports. However, if something is unclear in one of those documents, I provide suggestions in the overall written assessment.

Overall Assessment

The report was a useful application of statistical methods to assess behavioral changes around offshore wind farms, where many models were generated to answer important questions. This effort builds on recent syntheses on the topic, in particular supporting the recommendation that original data sets be aggregated and analyzed to investigate the phenomenon of behavioral changes around offshore wind farms (Lamb et al. 2024). However, the report itself was light on details without access to the GitHub repository, as the text often assumes you can glean details from the code database. I'm not sure that's a great strategy overall, and more information about modeling specifics should be incorporated into the report itself to allow it to stand alone.

Considering the report in isolation, I found some of the claims to be unsupported by the analysis shown, and I'm not sure that access to the repo would have resolved all these issues. A relatively small subset of models that can be effective in assessing spatial patterns and changes was addressed here, with some of the more common current methods like MRSea (Isojunno et al. 2025) and INLA (Viella et al. 2021) excluded. While these approaches might not always be optimal, they have been found useful in past efforts, and the reasons for excluding them from analysis here are mostly logistical. Using simpler models can be advantageous in some situations, and poor data quality might be a good reason to back off on implementing more complex models, but it still seemed strange to determine that these methods are not fit to compare with the approaches used here. If the methods used here are better then it would be best to directly compare the outputs and provide some new guidance on these methodologies.

Within the scope of the models that were assessed, this report walks through the basics of those approaches and provides useful model criticism. I found the section where the research questions from WP02 were evaluated to be particularly helpful and provided a useful summary of how these approaches could be applied. The model criticism would be improved by being more specific at times, but it all appeared logical, if high-level. A more detailed investigation of species models or data sets would be helpful to illustrate key points.

A more detailed assessment of each section follows:

Introduction

The report's framing makes sense, particularly in light of WPs 1 and 2. The identification of research questions was an important step, and while I had some smaller issues with the questions, they were good overall. My biggest issue was with the question about pooling data. Defining what is meant by 'pooling' is important here, and there should be instances where pooling data is useful even when there are differences across sites. For example, you could argue that a meta-analysis is a kind of data product pooling, and that would certainly be appropriate in a variety of circumstances. Overall, the descriptions of the data sets and what they could be used for were helpful and needed for the rest of the report.

Data Methodology

All the components of this section made sense, but this ended up being a high-level overview of this process. Some of these methods are okay to gloss over, but more information was needed in some parts, and the terminology could use a pass to prevent confusion. Clear references to WP-2 could be helpful for avoiding redundancy with past efforts when adding more detail.

Modelling Methodology

This is a breezy overview of many complex modeling frameworks. While the descriptions for these R packages generally matched my own experiences and expectations, these assessments were brief, and the criteria for decision-making were not made clear. More complex models were generally disregarded as being complex to use, having challenging documentation, or taking too long to implement. These things can be true, but are generally not considered good reasons not to implement a method. A broader discussion of how the model assumptions were or were not appropriate for each modeling would be more helpful here. As well as clearly defining the limitations on model run time or model complexity.

Generally, I had a few issues with the assessment:

- Modeling frameworks with more flexibility were discarded using logistical feasibility and computer time as examples – I don't think these are always appropriate rationales for choosing an analytical approach.

- More details was need with the non-linear models. There are many options for smoothed effects from packages like mgcv; more details are needed to understand how the effects were allowed to vary with lat/lon.

- Modeling frameworks with true spatial models were not seriously considered. Including models with complex spatial random effects using conditional autoregressive approaches or Matern covariance would help fill out this decision-space and provide a more robust comparison with techniques that are currently being used in the relevant literature (Viella et al. 2021; Anderson et al. 2022; Doser et al. 2024), and how does it compare to techniques employed by Garthe et al. (2023)? They seem similar, but I wasn't clear on how the s(lat, lon) effect compared.

Finally, a more detailed description of model validation and criticism is needed. Dharma is a great package, but discussing how you are using it and why these tests are important for your questions would be useful.

Data treatment – focal case

An example of how data are managed to prepare them for modeling is helpful for describing the issues involved in conducting these kinds of analyses. More so than the previous sections, the lack of access to the GitHub repo limited my ability to evaluate the efficacy of these decisions around data. Overall, the issues identified with this process generally matched my own expectations with these kinds of data sets. Generally, a few more details on the methods that were employed would be helpful here, even though I'm sure that they can be gleaned from the R code. Making the report stand on its own would prevent folks from having to check the GitHub repo for basic details about the methods that were employed.

Modelling results – focal case

As above, more details on the modeling methods would be helpful in understanding the case study better. Further, I would prefer equations to help explain how some of these models and parameters are being implemented. The language used to describe them is general, and I was sometimes confused as to the specific implementation.

Evaluating the model fit through a variety of tests was helpful to see in Figure 5. This evaluation should be extended to the Functional Redistribution models, aid the reader in understanding the differences between these approaches. The written description of the differences made sense, but a visual comparison would be illuminating. The figures for the Functional Redistribution model were great. Again, a comparison with the Simple model would be interesting, though I'm not sure it's as needed in this case.

General results

This section is nicely constructed. The figures showed the variety of observed patterns and the tables support the text nicely. I have a variety of suggestions in the text, but the overall organization looks good. The estimated redistribution functions in Figure 9 did lead me to wonder how good model fit was across all these scenarios. Perhaps an evaluation of model fit across all these species is needed to show which species are better suited for this effort than others. Some of the estimated relationships suggested a large amount of uncertainty, and some were high enough that I wondered whether convergence was an issue for some models.

Discussion

This is a well-organized and informative section. I appreciated the detail in the discussions on modeling decisions, and overall, the discussion was well-balanced with an experienced perspective. Connecting back to the original research questions and providing a useful evaluation of these research questions. The only thing missing was a section that synthesized your findings and presented clear recommendations for the future.

The commentary skewed a bit more toward practical considerations (modeling time vs. model appropriateness) than I prefer, but those issues should be addressed. Further, I found some of the discussion of Bayesian and frequentist modeling approaches to be inaccurate and should be revisited. Furthermore, there is extensive discussion of approaches that are not implemented in the present study. While discussing the potential upsides and downsides of using approaches not implemented here can be insightful, the lack of information on their performance in this context could be limiting. Again, I agreed with much of it, and it generally aligned with my own experiences, but more nuance could be incorporated.

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