OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

CARBON TRUST

AppSaS – Apportioning seabirds seen-at-sea

Project executive summary

February 2024

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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- Natural England
- Natural Resources Wales
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Who we are

Our mission is to accelerate the move to a decarbonised future.

We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions globally. From strategic planning and target setting to activation and communication - we are your expert guide to turn your climate ambition into impact.

We are one global network of 400 experts with offices in the UK, the Netherlands, South Africa, China, Singapore and Mexico. To date, we have helped set 200+ science-based targets and guided 3,000+ organisations in 70 countries on their route to Net Zero.

1. Introduction

Scottish Government has set a target to generate 50% of overall energy consumption from renewable sources by 2030 and to have decarbonised the energy system almost completely by 2050. Offshore Renewable Developments (ORDs) can make a significant contribution to these targets. However, the Scottish Government must ensure that ORDs are delivered in a sustainable manner in accordance with the requirements of the Marine Strategy Framework Directive (EC/2008/56), the Habitats Directive (EC/92/43) and the Birds Directive (EC/79/409).

One key challenge is that ORDs have the potential to affect seabirds that are protected by the EU Birds Directive, notably from collisions with turbine blades and through displacement from important habitat. The consenting process for developments which may interact with seabirds, may therefore involve assessing whether the development is likely to have an adverse effect on the integrity of SPAs.

In order to assess potential impacts on SPAs designated for breeding seabirds, it is necessary to determine whether seabirds potentially impacted by proposed offshore marine renewables originate from SPAs. The predicted effects are generally quantified in terms of the number of individuals at the development site likely to be affected. Effects are then attributed to appropriate SPAs in order to determine population-level impacts.

For at-sea distributions collected from ships or planes, the connectivity of observed birds to colonies is unknown. A range of traditional and new data have the potential to provide useful information on colony provenance of birds observed at sea and could therefore be employed to improve accuracy of apportioning tools during the breeding and non-breeding season. Existing apportioning methods include the NatureScot apportioning approach for breeding birds, Biologically Defined Minimum Population Scales and the Marine Scotland Apportioning Tool.

This project (AppSaS) aims to review these and other methods to improve the accuracy of breeding and non-breeding season apportioning of birds.

Accordingly, the aims and objectives of the AppSaS project are to reduce uncertainty in how the offshore wind sector apportions seabirds recorded during at-sea surveys to particular populations. This will enable more robust pre-consent impact assessments by:

- Considering how to establish connectivity between birds present in offshore areas at different times of the year, including the relative contribution of different populations to seabirds present offshore;
- Reviewing current approaches to apportioning by using empirical data and other evidence sources to validate their underlying assumptions;
- Identifying improvements to existing approaches or, if required, identifying and developing new approaches.

2. WP1. Review

The aim of Work Package 1 was to review the methods for apportioning seabirds at sea. There are a range of approaches available but in general, apportioning relies on being able to estimate (a) the size of each breeding colony and (b) the spatial distribution (e.g. utilisation distribution; UD) of the birds from each colony, because the proportion of birds originating from each colony will be proportional to the product of the colony size and the estimated spatial distribution of birds from that colony. Apportioning methods differ largely based on the sources of data and statistical methods used to estimate colony-specific spatial distributions, and in the sets of colonies or populations that they consider.

We identified the range of approaches available for apportioning, and then we reviewed the literature available to inform and assess each approach and assessed the strengths and weaknesses of each. We considered the following methods:

- Scottish Natural Heritage (SNH, now NatureScot) Apportioning Tool
- Marine Scotland Science (MSS) Apportioning Tool
- New methods using Global Positioning System (GPS) tracking data in a radial time-distance function approach
- Biological Defined Meaningful Population Scales (BDMPS)
- New methods for the non-breeding season based on light-level Geolocation (GLS) data

The different approaches offer varying strengths and weaknesses. Relevant to the breeding season, the SNH Apportioning Tool makes simplistic assumptions about distribution of birds at sea, but can be employed on all species. In contrast, the MSS Apportioning Tool includes more biological realism but is computationally more expensive and, at the time of writing of the review, is only available on four species. For the non-breeding season, the BDMPS method is at present the most widely used tool. The method is straightforward but makes a number of assumptions about distribution of birds of known provenance outside the breeding season. There is potential with new approaches using GLS data to better characterise colony-specific distributions in the non-breeding season. The methods all have merit and it was not possible to recommend one single way of carrying out apportioning, since much will depend on the nature of the species and data available. Expanding the MSS tool to more species, and undertaking the first quantitative investigation of the GLS method, however, emerged as two methods worthy of wider investigation in the breeding and non-breeding season, respectively, with the objective of introducing more biological realism.

3. WP2. Data identification and acquisition

The aim of Work Package 2 was to identify what information is required to support the improvement of existing apportioning tools or the development of new apportioning tools. Such information may be found either in published sources (e.g. peer- reviewed literature) or extracted from databases or other data stores. We listed the key information requirements needed to improve, or develop new approaches for, apportioning.

Based on this review, we produced a detailed list of data sources that could be used to improve methods for apportioning. We carefully considered the utility of each of these data sources to addressing the key information needs in order to support improvements to the methodologies for apportioning. We assessed the strengths and biases associated with each of these data sources.

Following this process, we proposed which data sources are the most promising and should be taken forward into WP3 for methods evaluation.
We considered the following methods:

- GPS tracking data
- Focal follow data
- Geolocation data
- Data from local bird reports
- Literature on timing of migration
- Online databases: Trektellen, BirdTrack and eBird
- Colony-specific data on phenology
- Ring recovery data
- Biometric data
- Genetic marker data
- Stable Isotope data
- Ectoparasite data

Approaches to apportioning are underpinned by habitat use models informed by tracking data. We summarise the covariates used by the Wakefield et al., (2017) models that underpinned the MSS Apportioning Tool, and highlighted additional variables that may be of relevance to the additional species, particularly lesser black-backed gulls:

- Colony size
- Seabed relief
- Seabed substrate
- Potential Energy Anomaly
- Sea surface temperature
- Alpha chlorophyll
- Thermal fronts
- Distance to coast
- Vessel movement data

In relation to the breeding season data, the GPS tracking data and the tern focal follow data are suitable for use in the MSS Tool, requiring new modelling of these data. We identified the necessary data sources for the covariates to run these models, and established their availability and suitability for the modelling. In relation to the non-breeding season data, we determined that the geolocation data available for Guillemots and Razorbills is likely to be suitable for bespoke non-breeding season apportioning, based on kernel density estimation. We concluded that the two highest priority situations in which new or extended methods were likely to rapidly provide added value, and therefore formed the focus of methods evaluation in WP3, were those associated with lesser black-backed gull GPS and auk GLS data.
Regarding the other data sources identified, we felt that the spatial and temporal resolution of these data is coarser than that available from either the GPS or geolocation data. Biases in the distribution of effort for ringers and observers means that data from ring recoveries is unlikely to give a clear picture in relation to the origins of ringed birds. Similarly, using genetic markers to identify the origins of birds is likely to be challenging due to a lack of population structure. While there are clear trends in biometric data with latitude, variation in body size between birds from the same breeding colony mean using these data to apportion wintering birds back to their breeding colonies is unlikely to be practical. In conclusion, while there may be some value in using ringing, genetic or biometric data in this context, the challenges of working with these data mean that they are unlikely to be suitable for apportioning at present.

4. WP3. Method evaluation

The aim of Work Package 3 was to evaluate apportioning methods identified during WP1 by utilising the datasets with the most potential from WP2 to determine their consistency and assess their strengths/weaknesses. WP1 demonstrated that only a limited number of apportioning methods have been used in the UK context. WP2 identified a number of potential data sets that could potentially be used to either develop new methods or extend existing methods, and could be used to evaluate these methods against existing approaches. Two high priority situations in which new or extended methods were likely to rapidly provide added value were selected for these developments.

The first development was to extend the spatial distribution mapping approach of Wakefield et al. (2017) to include a new species, lesser black-backed gull, for which suitable GPS tracking data were available. To date the method developed by Wakefield et al. (2017) had only been tested on four species (common guillemot, razorbill, black-legged kittiwake and European shag) and for all remaining species it was necessary to use the SNH/NatureScot Apportioning Tool, a simpler method that makes strong assumptions, and does not utilize all available data. As such, any opportunity to extend the Wakefield et al. (2017) method to a new species during the breeding season is a significant advance.

The second development was concerned with apportioning in the non-breeding season. The current method for non-breeding season apportioning is BDMPS, an approach that considers broad scale regions of UK waters. Here, we developed an alternative approach using geolocation (GLS) tracking data of guillemot and razorbill in the non-breeding season (Buckingham et al., 2022). We used these data to develop maps that can be used for apportioning, while incorporating a quantification of uncertainty. Incorporating uncertainty was an important advance since location accuracy of geolocation data is much lower than with GPS data.

The apportioning approach taken for lesser black-backed gulls followed the approach in Wakefield et al. (2017). We used statistical models to link relative abundance to a range of explanatory variables that relate to accessibility, competition and environmental conditions. We then converted these into apportioning percentages, following Butler et al. (2020). The input data were GPS tracking locations of breeding adults from six sites between 2010 and 2020, comprising a total sample size of 207 deployments. In order to translate these into apportioning estimates, a post-hoc adjustment was applied to the outputs of these models to account for the proportion of time spent foraging on land, since this can be substantial for some breeding populations of this species in the UK.

The new summer GPS-based lesser black-backed gull maps (i.e. the spatial distributions not apportioning percentages) were evaluated against the inverse distance square relationship that underpins the NatureScot tool at two colonies. The core areas of the utilisation distribution estimated using the new models developed here differed from that predicted by the NatureScot approach at one colony, whereby they were more localised and the overall distribution of the colony was somewhat more elongated, and matched the tracking data from the colony. In contrast, the distributions predicted for the other colony were quite similar between the two approaches.

The apportioning approach taken for the GLS data from guillemots and razorbills involved estimating colony-specific Utilisation Distributions (UDs) following the approach in Buckingham et al. (2022), and extrapolating to provide distributions for untracked colonies in the vicinity of the subset of colonies where birds were tracked. The analysis had to account for three main differences between GLS and GPS data: a) Geolocation data are much lower frequency than GPS data; b) Levels of observation error in geolocation data are much higher than for GPS data; c) The levels of observation error in geolocation data are likely to be heterogeneous. The input data were GLS tracking locations of breeding adults from nine sites between 2017 and 2021, comprising a total sample size of 418 guillemot data sets and 136 razorbill data sets. The analysis involved deriving spatial locations from GLS data and estimating UDs from these locations using kernel density estimation. Uncertainty associated with each track was propagated through the kernel density estimation to ensure that it was quantified within the outputs of the spatial mapping. This was achieved by estimating UDs separately for each simulated track within each of 100 iterations, leading to the production of 100 simulated kernel density estimates for each tracked colony for each month of the non-breeding season. These were then aggregated up to a seasonal level for each iteration, and 2.5% and 97.5% quantiles extracted in order to capture the impact of the locational uncertainty in the GLS data on the estimated spatial distribution.

The new winter GLS-based spatial distributions for guillemot and razorbill were evaluated in three ways: a) Visual summaries in the form of maps; b) Comparison with BDMPS: GLS-based maps were apportioned to BDMPS regions (UK North Sea and Channel waters, UK Western waters, and Outside of the UK) and summary tables were collated by species, SPAs, and season from the BDMPS tables with estimated mean and lower and upper 95% CIs of proportions and compared to spatial distributions derived from the GLS data; c) Space time cubes developed in this project to characterise and visualise fine-scale temporal shifts in space use, and thereby to investigate the plausibility of the assumption underpinning the GLS-based maps, that temporal change – aside from systematic differences between months/seasons – can be ignored.

Visual summaries were presented as maps of mean, lower and upper 95%CI, which were produced for each population in each season, and gave a visual representation of the level of uncertainty relative to the magnitude of the mean. The BDMPS proportions of birds in each region fell outside the range of uncertainty for the equivalent GLS-based results for almost all colonies for guillemots in the non-breeding season and razorbills in the migration season, although accordance was much higher for razorbills in the winter season. The results of the visualisation using space time cubes suggested that the assumption of a static distribution throughout the non-breeding season was more appropriate for some colonies than others.

In delivering these two examples, WP3 fulfilled two main objectives: to broaden estimation of underpinning distributions used in apportioning calculations to new species and seasons, and to compare methods of generating colony-specific distributions underpinning apportioning calculations. Both new approaches represented an improvement on the currently used approach, as they incorporated more biological realism. The results of the GPS data from lesser black-backed gulls showed broad similarities between the GPS-based maps in the NatureScot tool. In contrast, we found substantial differences between the GLS-based maps of guillemots and razorbills and BDMPS. Note that the focus here was on an evaluation of underlying spatial distributions using different methods. Within WP4, these distributions were converted into apportioning estimates.

5. WP4. Tool development

The aim of Work Package 4 involves translating three aspects of functionality into user-friendly tools: (1) novel GLS-based apportioning estimates for the non-breeding season for razorbill and guillemot, (2) novel GPS-based apportioning estimates for the breeding season for lesser black-backed gulls and (3) extensions to the NatureScot apportioning tool. The first of these has involved substantial work within WP4, in part because the functionality included within this tool goes beyond that in the current apportioning tool (BDMPS), and in part because of technical challenges in using the GLS-based maps. As a result, and because integration into the Marine Scotland Cumulative Effects Framework (CEF) involves addressing some challenges, this part of the work has been delivered through a self-contained tool (albeit one that is futureproofed for future inclusion in the CEF).

The stand-alone Apportioning in the Non-Breeding Season (ANBS) tool for apportioning guillemots and razorbills in the non-breeding season is available to download on Github with an accompanying User Guide.

The tool is based on monthly estimates of the spatial distribution of guillemot and razorbill from tracked colonies through the non-breeding season derived from geolocation data, together with associated quantification of uncertainty (WP3), and the results compared against BDMPS at the level of BDMPS regions.

The User Guide is an accessible user-facing document for the tool, and provides a practical, non-technical, description of the steps involved in running the tool using the open-source software R. The tool produces outputs in the form of an automated PDF report, and examples of this report are included to illustrate the content and format.

The report does not seek to duplicate the User Guide or worked examples, or the WP3 report, but instead provides additional context by (1) outlining the justification for the methodological approach taken within the tool, (2) describing the inter-relationship between this tool and other products and tools (primarily the CEF), and (3) by outlining future work, including the potential for future integration of the tool into the CEF.

The structure of the tool is similar to that used for current breeding season apportioning tools: users have the option to either select map mode (colonies of interest are selected and mean estimates of apportioning with uncertainty are mapped), or footprint mode (mean estimates of apportioning and uncertainty are estimated from relevant colonies for the area of an uploaded footprint). Unlike in breeding season tools, however, users can select the month or season that they wish to consider, since the GLS-based maps are monthly. Given the variation in spatial distribution between months and the challenges in producing biological definitions of seasons, this flexibility is designed to allow users to be able to use the tool to either apportion for seasons, whose start and end months they can specify, or for individual months.

For the geolocation-based models to be used for apportioning it was necessary to either be able to use these models to produce spatial distributions for colonies without GLS tracking data, or else to use an alternative approach for colonies without GLS tracking data. The only obvious alternative approach to use in this context was BDMPS. Since there are limitations to BDMPS, we extrapolate the geolocation-based models out to colonies without GLS tracking data where these colonies are within a certain distance threshold GLS-tracked colony, and use BDMPS where the distance to the nearest colony with GLS tracking data exceeded this threshold.

Within each simulation each untracked colony is assumed to be associated with a particular tracked colony. Tracked colonies that are closer to the untracked colony are therefore more likely to be selected than those that are further away. This process is similar to the calculation of a spatial distribution based on a weighted average of distributions for colonies with tracking data but differs in explicitly accounting for the uncertainty associated with the linkage of untracked to tracked colonies. The predicted number of birds from each colony in each grid square is calculated to be the utilisation distribution (UD) for that colony multiplied by the colony size. This calculation is performed separately for each simulated UD, allowing uncertainty to be propagated through the calculations.

We apply the tool to a set of five case studies, which are designed to show the different options of input parameters, including using the footprints. However, the case studies are not exhaustive in terms of input parameters, they are rather designed to show examples of the different options that can be used within the tool. In the appendix of the User Guide, we show the output reports generated by the five worked examples, in order to illustrate the format of the output reports.

Although the ANBS tool has been developed as a stand-alone tool, and is not currently integrated into the CEF, the outputs from this tool can be used as inputs within the CEF. Within the structure of the CEF, apportioning constitutes a user-defined input, rather than one of the main set of linked tools, so the CEF allows functionality for users to specify apportioning proportions directly. Default apportioning values for the non-breeding season in the CEF are derived from BDMPS, but users can opt not to use these, and instead to input their own values based on the outputs from this tool.

The tool has been designed and structured to be integrated into the CEF in as straightforward a way as possible. The datasets that are used both in the ANBS tool and the CEF use the same structure as in the CEF (for folders, naming and versioning), making it uncomplicated to align these with the CEF in future.

The tool is designed to be as straightforward as possible to update in future as future datasets and model outputs become available. The process for updating the data, or to futureproof against all such updates in situations where the data structure changes, will depend on the exact nature of the changes that have been made, and the exact format of the revised/additional data.

The report details improvements to the tool that could be incorporated in future.

In WP3, GPS tracking data from lesser black-backed gulls (LBBG) were used to model the spatial distribution of LBBG for colonies around Britain and Ireland. Colony-specific habitat use was modelled by examining the relationship between bird habitat use and several covariates for colonies where GPS tracking data were available, and using this model to predict the distribution of birds from untracked colonies. We also adapted the models to allow for movement of birds across areas of land when assessing habitat accessibility, an adjustment which was not necessary for the seabird species considered previously using this approach (guillemot, razorbill, kittiwake, shag). LBBG distribution was found to be related to distance from the colony, habitat availability, competition, and the at-sea environment (depth). The resulting predicted colony-specific distributions were saved, alongside colony counts from the Seabird 2000 survey, to allow these results to be incorporated into an apportioning tool.

During analysis of the LBBG tracking data, it was observed that the time spent on land differed substantially between tagged individuals from different colonies. As these differences would likely alter the predicted density of birds attributed to at-sea locations during apportioning calculations, it was necessary to explore and incorporate these differences further during WP4.

Colonies were divided into two types, urban and non-urban. Colonies were classified as either urban or not urban following recent methods used in developing urban survey design protocols for large gulls. GPS tracking data are available for colonies within each of these two types, so we calculated the mean proportion of time spent on land by averaging across the tracked colonies within each type (urban: 98.87%; non-urban: 89.9%). Note, however, that there was considerable uncertainty associated with these estimated means (standard deviation of 3.1% and 13.6% respectively).

The GPS-based apportioning calculations for lesser- black gulls will be integrated into the Cumulative Effects Framework (CEF), a user-friendly web-based framework that incorporates a wide range of data relevant to UK assessments and allows assessment tools to be linked together, and to those data, in a transparent way. The integration of the LBBG apportioning calculations into the CEF is relatively straightforward, because it simply involves extending existing functionality within the CEF to be available for an additional species. As such, the changes to the CEF involved in integrating LBBG breeding season apportioning into the CEF are an extended set of user options if users are running the CEF for lesser black-backed gulls and the addition of new data files to datasets into the CEF Data Store to support this.

The incorporation of the LBBG work from this project into the CEF allow users to select between three possible breeding season apportioning methods: Method 1a: Distance decay and foraging range apportioning using "distance by air", with inland colonies included; Method 1b: Distance decay and foraging range apportioning using "distance by sea", with inland colonies excluded; Method 2: GPS-based maps, with inland colonies excluded. The additional functionality has required the addition of new data files to datasets within the CEF Data Store.

Work to validate and potentially divide these coarse groupings of urban and non-urban into further, biologically relevant, sets of colonies would be a valuable extension to this initial analysis. Additional tracking across colonies, particularly at urban sites (where sample sizes are currently low), would help to improve the precision of estimates for the mean proportion of time spent on land in urban and non-urban sites.

The report also considered NatureScot Apportioning Tool (inverse distance decay) extensions. The NatureScot (previously SNH) Apportioning Tool assumes that for a particular location or area at sea, the proportion of birds arising from each breeding colony is proportional to the population size multiplied by the inverse squared distance by sea from the location to the colony, divided by the proportion of the area within the foraging range that is sea.

In the absence of GPS tracking data, however, it is still possible to extend the NatureScot Tool so that it estimates the rate of decay of bird density with distance empirically for each species, using published foraging ranges, rather than fixing densities to always decay in proportion to inverse distance squared.

We estimated decay rates associated with published foraging ranges searching across a range of possible values for the decay rate, and, for each set of published foraging ranges, identified the decay rate that provides the best match to the ratio of mean to maximum foraging ranges.

For all species for which the distance and foraging range (“NatureScot”) apportioning is available, the CEF functionality has been extended, by addition of a new input into the user interface, to allow an extended version of the apportioning tool to be used. The extension to the interface allows users to specify the value of the rate of decay; the value of this parameter was previously fixed to be equal to two within the CEF, so could not be specified by users. Because they estimate the values using only two pieces of information, the resulting estimates are therefore likely to be very sensitive to any inaccuracies in values of mean and maximum foraging range used.

Simple distance-decay relationships are unlikely to capture all of the key characteristics of colony-specific spatial distributions, so approaches that use a wider range of empirical data (e.g. GPS or GLS tracking data) and also account for the effects of competition and environmental variation are likely to provide more accurate estimates of apportioning. The simple extension of the NatureScot apportioning tool described here is therefore a straightforward interim solution to try to investigate the performance of the existing model, and, where appropriate, to extend it, but it would ideally ultimately be superseded by additional data collection and associated modelling.

We compared breeding season apportioning methods, comprising two general methods – a distance-decay and foraging range approach, or an approach based on GPS-based maps. The latter approach is now available for five species (whereas it was previously, prior to this project, available for four). The distance-decay approach is available for a wider set of species (in the CEF for 13 species). The distance-decay approach depends upon the choice of foraging range, and this project has also allowed the decay parameter within it to be varied. We compared results obtained using the distance decay and GPS-based apportioning methods, using different implementations of the distance-decay approach.

We considered twelve species (all of the species considered in the ORJIP Seabird Sensitivity Mapping Tool, with the exception of Red Throated Diver; this species is excluded because it lacks the data required to implement the apportioning methods).

The results suggest that the correlations are very high when comparing proportions obtained from different decay parameter values (always > 0.98), and relatively high when comparing the GPS-based approach against the distance decay approach with mean-max foraging range (always > 0.95).

6. WP5. Review of Reports on WP1, WP2 and WP3

The aim of Work Package 5 was to provide an independent technical review of the reports produced under work packages 1, 2 & 3 of the ORJIP AppSaS project. No comments are provided on possible improvements for the project report per-se, since these were considered completed. Rather, they were broader suggestions for future progress in this area, such as the production of peer-reviewed scientific papers. The report provided the following summary:

- WP1 reviewed the existing methodology on apportioning of seabird marine usage to different colonies of origin. This is a comprehensive and comparative contribution to this area of the applied ecology literature and sets out the basis for future methodological developments. It should eventually be published as a review paper.
- WP2 reviews and collates available data for use in apportioning methods. The report meshes well with the preceding review of methods and the data base of available data layers should be an invaluable resource for the industry, if maintained and suitably shared for future modelling.
- WP3 is a more extensive report that contains two large pieces of work applying habitat modelling to the summer distribution of lesser black backed gulls and density estimation modelling to the winter distribution of guillemots and razorbills. These extensions present some methodological novelty, but their main contribution is applied and species-specific. So, they should each separately find a home in good journals in the applied/avian/marine literature.

- Overall, there is an extensive body of work represented in these reports, characterised by a high level of statistical attention, and informed by detailed biological insights, an effective synergy between expert statisticians and seabird ecologists. Recommendations are made mainly to facilitate the work's route through peer review and to offer constructive proposals for further analytical development.

7. Conclusions

The ORJIP AppSaS project delivered valuable new insights of relevance to apportioning methods utilised in assessments of offshore renewable developments (ORDs).

In WP1, we reviewed the methods for apportioning seabirds at sea. We considered five methods: a) Scottish Natural Heritage (SNH, now NatureScot) Apportioning Tool; b) Marine Scotland Science (MSS) Apportioning Tool; c) New methods using Global Positioning System (GPS) tracking data in a radial time-distance function approach; d) Biological Defined Meaningful Population Scales (BDMPS); e) New methods for the non-breeding season based on light-level Geolocation (GLS) data

In WP2, we identified what information is required to support the improvement of existing apportioning tools or the development of new apportioning tools. We collated data of a range of different types from multiple sources. We concluded that the two highest priority situations in which new or extended methods were likely to rapidly provide added value, and therefore formed the focus of methods evaluation in WP3, were those associated with lesser black-backed gull GPS in the breeding season and auk GLS data in the non-breeding season.

In WP3, we focused on providing new apportioning methods, in these two key situations i.e. breeding season apportioning for lesser-black backed gulls and non-breeding season apportioning for guillemot and razorbill - and in evaluating the spatial distributions that underpin the new methods against those that underpin the existing methods.

In WP4, the spatial distributions that have been produced and evaluated here were converted into apportioning estimates. A stand-alone Apportioning in the Non-Breeding Season (ANBS) tool was developed for apportioning guillemots and razorbills in the non-breeding season. Further, we integrated new functionality on breeding season apportioning of lesser black backed gulls, into the CEF. The conversion into apportioning of lesser black-backed gulls required adjustment to account for proportion of time spent foraging on land, and for guillemot and razorbill the use of a hybrid approach that combined GLS-based spatial distributions (where appropriate) with BDMPS (for colonies that lie far from the nearest colony with GLS data). The apportioning estimates obtained using different methods were evaluated against each other. This work package has therefore translated the results of the analyses of WP3 into practical tools.

The WP5 report was an independent technical review of the reports produced under work packages 1, 2 & 3 of the project, providing recommendations to facilitate the work's route to peer review publication.

We consider there to be two concrete modelling advances that can feed into assessments:

- The ORJIP AppSaS provides novel information on apportioning for lesser black-backed gulls in the breeding season by using GPS tracking data to derive colony-specific spatial distributions, avoiding the need to use more simplistic distance-decay approaches, and thereby enhancing the use of empirical evidence in informing the consenting process.

- Further, the ANBS tool reduces consenting risk by quantifying uncertainty in the non-breeding season for auks. Using a hybrid approach to derive apportioning dependent on data available at each colony, the tool undertakes a comprehensive assessment of apportioning in the non-breeding season throughout the UK, with confidence intervals.

8. References

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