OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

Quantification of mortality rates associated with displacement (QuMR)

Appendix – B

May 2025

working to accelerate offshore consenting

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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- Joint Nature Conservation Committee (JNCC)
- Natural England
- Natural Resources Wales
- NatureScot
- Scottish Government's 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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Contents

Abbreviations

Term	Description
EE	Expert Elicitation
ORJIP	Offshore Renewables Joint Industry Programme
WP	Work Package

1. Recommendations

Using expert elicitation results in the displacement matrix tool for assessments

In this section we provide recommendations on the usage of the expert elicitation results for the mortality rate of displaced birds (hereafter '*displacement mortality rate*') within the main tool that is currently used in assessing risk from displacement – the "Displacement Matrix", which requires this parameter as an input to the tool.

A very broad operational definition of the displacement mortality rate is that it is equal to the ratio of the absolute level of displacement mortality from a windfarm to the number of individuals experiencing displacement by a windfarm, so that the absolute level of displacement mortality from a windfarm is equal to the number of individuals experiencing displacement by a windfarm multiplied by the displacement mortality rate. The number of individuals experiencing displacement by a windfarm can itself, in general, be calculated to be equal to the baseline number of individuals using the windfarm footprint area prior to construction multiplied by the proportion of these individuals that would experience displacement if there were a windfarm (the "displacement rate"). The absolute level of mortality is therefore equal to:

*Absolute level of displacement mortality from a windfarm = Baseline number of individuals using windfarm * Displacement rate * Displacement mortality rate*

[Equation 1]

The current Displacement Matrix approach, which is extensively used in assessments, performs this calculation for a pre-specified set of values for the displacement rate and displacement mortality rate. A range of values for both of these parameters are used to provide a visual means of examining the consequences arising from the uncertainty associated with both rates. Within the current Displacement Matrix approach the baseline number of individuals using the windfarm is defined in a specific way -- as the maximum monthly estimated baseline abundance within the windfarm footprint within the season of interest, as estimated using at-sea survey data. The current approach focuses only on individuals that use the windfarm and so does not account for indirect effects on individuals that do not use the windfarm but may be impacted by it – e.g., in particular, it does not account for indirect effects on chicks driven by displacement impacts on breeding pairs.

There is currently no direct empirical evidence regarding the displacement mortality rate (see WP1 report), leading to considerable uncertainty in the appropriate parameter values to use within the Displacement Matrix tool. The expert elicitation (EE) within this project used expert judgement to assign values to the displacement mortality rate, for six species in breeding and non-breeding seasons. The displacement mortality rate is a key input to the Displacement Matrix approach, so the results of the EE have clear relevance to the way that the Displacement Matrix is used and should be considered in relation to updating SNCB guidance for this approach. However, there are a number of important issues that need to be taken into account when using the results of the EE within the Displacement Matrix approach:

(1) the way in which the EE accounts for uncertainty and variability
(2) the way in which baseline abundance is estimated within assessments, and how this relates to the biological interpretation of seabird space use of windfarm footprints developed by the experts and used to frame displacement mortality rate estimation within the EE
(3) the fact that the EE produced separate estimates for indirect displacement effects on chicks as well as for direct effects on adults

Issue 1: The approach that the EE uses to account for uncertainty and variability

The current displacement matrix approach uses pre-specified ranges of values (defined by the regulator and their advisors) for the displacement rate and displacement mortality rate. The EE results differ from this in two important ways:

1. They provide a probability distribution, rather than a discrete set of fixed values.

2. They provide a separate distribution for each expert, rather than providing a single overall distribution or range.

These differences have consequences for the potential use of elicited values for displacement mortality rates within the current UK assessment framework. It is generally recommended that the distributions for individuals experts are used, rather than pooling these distributions, to retain the uncertainty from the EE that arises from differences between individual experts. A simulation-based approach could be used to capture uncertainty both within and between experts: within each of a large number of simulations, a random expert is first selected, and a value of the displacement mortality rate is then simulated using the probability distribution for this expert. The simulated rates therefore capture both sources of uncertainty – uncertainty associated with the estimate provided by each expert, and uncertainty arising from variation in estimates across all experts involved in the EE.

The Marine Scotland CEF project has developed a simulation-based approach to propagate uncertainty between individual assessment tools and provides the functionality for a set of simulated displacement mortality rates to be provided. Each rate is then converted into absolute displacement mortality, using Equation 1, and this is propagated through the subsequent stages of modelling (e.g., Population Viability Analysis) using the simulation-based approach. This functionality could allow for the uncertainty captured in the EE to be used within the assessment process via the CEF (both in terms of differences between experts, and within the probability distribution resulting from each individual expert's judgements). This simulation-based approach for propagating uncertainty should, in principle, allow the current approach, of applying precaution at each modelling step within the assessment process, to be avoided: by propagating uncertainty through the whole process, the simulation-based approach should allow precaution to only be considered at the final step in the chain of models, because the uncertainty at this final step has incorporated individual components of uncertainty from each earlier step in the assessment process.

A practical challenge, however, is that the extent to which uncertainty is quantified currently varies considerably between tools and steps in the assessment process. In the context of the Displacement Matrix, a key challenge lies in how the probabilistic quantification of uncertainty in the Displacement Mortality Rate arising from the EE can be combined with the way that uncertainty is accounted for in the Displacement Rate. Because uncertainty in the Displacement Rate is currently dealt with in a non-probabilistic way, and it is difficult to combine uncertainties obtained using probabilistic and non-probabilistic approaches, this requires further research, such as a meta-analysis of existing studies estimating displacement rates, or expert elicitation to quantify the uncertainty associated with displacement rates.

Issue 2: Definition of baseline bird abundance for use in the Displacement Matrix

The current Displacement Matrix approach defines the baseline number of individuals using the windfarm to be the maximum monthly estimated baseline abundance within the windfarm footprint in the season of interest, estimated from at-sea survey data. This quantity can be calculated directly from data that are routinely collected, so is in operational terms, straightforward to use.

However, during the EE the experts considered whether it was possible to provide judgements on the displacement mortality rate in the context of the way in which baseline bird abundance is currently estimated in Displacement Matrix approach. The experts concluded that this was not possible because the definition of baseline abundance is broadly incompatible with a biological understanding of seabird space use patterns over time, including biological processes such as turnover, fidelity in space use, and behavioural patterns associated with breeding pairs and attendance of offspring.

The experts in the EE therefore defined the Displacement Mortality Rate using a biological, rather than operational, definition of the extent to which seabirds use the windfarm footprint, which then allowed them to meaningfully provide judgement on the values of the displacement mortality rate. The specific definition that was adopted related to any:

"Individual bird or their dependents and inter-dependents that would have used the area of influence of the offshore wind farm and associated infrastructure if there had been no offshore wind farm."

hence, the elicited mortality rates were specifically defined as:

"The excess mortality rates (as an absolute %) for an individual bird or their dependents and inter-dependents that would have used the area of influence of the offshore wind farm and associated infrastructure if there had been no offshore wind farm, but which is displaced away from the area during construction and/or operation."

This definition implicitly assumes that the displacement mortality rate applies to all individuals that experience displacement at any point during the season of interest. This, in turn, implies that the baseline abundance that is effectively being used in defining the displacement mortality rate is the **total number of individuals that utilise the windfarm footprint, during the baseline period, at any point during the season of interest**. The experts stated that this definition was likely to result in very different numbers of birds than the one used in the current assessment process based on at-sea surveys.

The level of baseline abundance used in the EE definition of the displacement mortality rate is, therefore, likely to be substantially different to that used in the current Displacement Matrix approach. The baseline abundance level used in the EE definition might be expected to be both systematically and potentially substantially larger than that used in the current displacement matrix approach. This systematic difference arises because the EE definition accounts for turnover in space use of birds at sea, whereas the current Displacement Matrix definition does not. The EE definition considers all individuals that *ever* use the windfarm footprint during a particular season, whereas the Displacement Matrix definition focuses only on the number of individuals using the footprint at a particular point in time (albeit that with high abundance, amongst the points at which surveys occurred).

Our belief is that it is not appropriate to use the displacement mortality rates arising from the EE within the Displacement Mortality in its current form, unless adjustments are made to account for this discrepancy. We consider a simple example to demonstrate the potential variation in mortality levels arising from this mismatch, in which the baseline abundance is 200 individuals based on the definition in the current Displacement Mortality approach (e.g., from at-sea surveys), versus a value of 800 individuals according to the definition used in the EE (e.g., all *individual birds or their dependents and inter-dependents that would have used the area of influence of the offshore wind farm and associated infrastructure if there had been no offshore wind farm*). If we assume the EE estimated a single displacement mortality rate of

1%, then when this EE displacement mortality rate is used in combination with the baseline abundance value from the current method for the input to the Displacement Matrix (at-sea surveys) the resulting mortality level will be just 25% (e.g., 100 * [200/800]) of the value arising from the application of the definition used in the EE process. To adjust for this discrepancy, the baseline abundance from the current Displacement Matrix could either be multiplied by the ratio of the baseline abundances (800/200 = 4) before combining it with the displacement mortality rate from the EE, or, equivalently, the displacement mortality rate from the EE could be multiplied by this ratio prior to combining it with the baseline abundance from the current Displacement Matrix approach. However, we currently lack an agreed methodology for how these conversions could be applied, and the precise way in which conversion values should be calculated.

This adjustment or conversion fundamentally relies on estimating **turnover** in space use of seabirds at sea:

"The ratio of the number of birds that ever use the windfarm footprint at any point during the season of interest to the number of birds estimated using the peak monthly at-sea survey."

Turnover is influenced by site fidelity (e.g., from individuals choosing to similar foraging locations over time), but is also affected by daily time budgets, particularly in breeding pairs in which attendance of chicks is critical to chick survival. This is because even if individuals always forage in the proposed windfarm location, they will still spend only a proportion of their time in the windfarm area (and therefore be available to be counted within at-sea surveys) because they must engage in other activities such as returning to the nest to attend their chicks and relieve their breeding partner. Turnover cannot be estimated using at-sea survey data because at-sea surveys do not track the extent to which the same individuals are observed in different surveys, so needs to be estimated using other data sources. GPS tracking data can provide a way of estimating turnover values, because it tracks specific individuals over time. There are, however, challenges in using GPS tracking data for this purpose, such as datasets tending to focus on a subset of the population and typically tracking individuals for part of a season over relatively short time periods. Expert elicitation could provide another possible approach for estimating turnover rates in the absence of sufficient GPS tracking data for each species and location of interest, as turnover is likely to vary in both space and time depending on environmental characteristics and lifecycle phase.

A previous project funded by Marine Scotland considered processes relating to, and estimates of turnover for some seabird species in one region of the North Sea (Searle et al. 2015), providing recommendations for how turnover could be estimated, and the potential extent to which it could affect estimates of the number of individuals using a discrete area of space derived from at-sea survey data. Key inference from this project was as follows:

- The turnover values calculated could, in principle, provide a basis for scaling the abundance estimates of breeding individuals obtained during bird surveys of a particular area (such as a wind farm footprint) up to estimates of the number of breeding birds that are using that area during the entire breeding season. However, there were three key reasons why considerable caution needs to be taken in trying to do this:

    - The results were contingent upon particular scenarios regarding the level and spatial scale of site fidelity, which is currently unknown for most species of interest. The results therefore provide a guide to assess how the level of turnover changes with site fidelity behaviours and patterns, and with the spatial scale of wind farm footprints, but they cannot provide specific estimates of turnover until further data on both the level and spatial scale of site fidelity of these species become available.

    - The literature review in the project highlighted the considerable variability in seabird foraging ranges and foraging trip characteristics both within and between species, and within and between years – all of which will affect estimates of turnover. This variation may translate into among-population and inter-annual differences in turnover of individuals at sea that should be considered when assessing the potential impacts of offshore renewable energy developments on breeding seabirds.

- Current methods for surveying seabirds at-sea cannot achieve a complete census of all birds within an area the size of most windfarm footprints. At-sea surveys will, therefore, generally be a sample, rather than a complete census, and will typically take place over a longer time period rather than at an instantaneous snapshot. In order to scale actual survey data (e.g., at-sea surveys) up to the total number of birds in the area it is necessary to use statistical adjustments to account for factors other than turnover, such as non-detection. In addition, at sea survey estimates cannot distinguish between breeding and non-breeding individuals, nor assign birds to specific colonies. An additional step is required to adjust the at sea estimate by the proportion of non-breeding birds and to assign remaining birds to the appropriate colony or population of interest.

Issue 3: Impacts on chicks

Implementing the EE estimates for impacts of displacement on breeding success of affected adults is in principle straightforward, as it produces a change in breeding success for affected birds which may be used within a PVA in the same way that any change in adult mortality is implemented. However, such an implementation encounters the same challenge described above, namely the discrepancy between how inputs for the Displacement Matrix are currently calculated and the definition assumed within the EE of impacts on adults and chicks – how to reliably estimate the number of adult birds that would have used the area of influence of the offshore wind farm and its associated infrastructure at any time during the season of interest. Consideration would also have to be given to the breeding state of individuals observed in at-sea surveys when making this adjustment for impacts in the breeding season. For many species it is not possibly to separate breeders from non-breeders (e.g., adults from immatures, or to identify adults that are not breeding but still in using the area around a breeding colony) in aerial survey data. As with the previous recommendation, both GPS tracking data and expert elicitation could be used to estimate the adjustment needed to convert estimates of all birds observed within at-sea surveys to estimate the number of breeding birds likely to be using the area of sea at any point during the breeding season. This will require further research to develop a standardised and reliable method.

Research recommended to facilitate use of the EE outputs within the Displacement Matrix, and to improve estimates of displacement mortality rates:

- Interrogation of GPS tracking data to estimate rates of fidelity in seabird species, including influence of environmental variation and seasonal variation.

- Examination of seabird time-activity budgets to understand influence of division of behaviour between at-sea and colony behaviours and how this might be used to adjust at-sea survey data.

- Tracking of individual birds to link observed interactions with operational offshore windfarms (barrier effects and displacement) with subsequent demographic rates (breeding success and survival).

These recommendations relate to research that is needed to provide underpinning evidence upon which a decision to use the elicited displacement mortality rates within the Displacement Matrix approach should be based (via a conversion for the number of birds likely to be using the area of interest over the course of each month and/or season). At present, we believe we do not have the required research evidence to estimate robust turnover values that could be used to convert abundance estimates and thus enable the direct application of the mortality rates generated by the EE process within the Displacement Matrix. Whilst these research outputs would enable this conversion of at-sea survey counts to allow for the use of the elicited rates in the Displacement Matrix, it is likely that uncertainty around the form and magnitude of this conversion will persist. Therefore, it will ultimately be up to regulators to determine guidance on how to implement the new research findings to enable the use of the elicited values within the Displacement Matrix approach.

References

Searle KR, A Butler, D Mobbs, M Bogdanova, S Wanless, M Bolton and F Daunt. 2015. At-Sea Turnover of Breeding Seabirds. Scottish Marine and Freshwater Science Volume 6 Number 10. DOI: 10.7489/1622-1

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+44 (0) 20 7170 7000

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Report on the Expert Elicitation Workshop for Quantifying Displacement Mortality Rate in Seabirds

Prepared for ORJIP Offshore Wind

[September 2022]

Bird Expert Elicitation Workshop Report

Prepared by DMP Statistical Solutions UK Ltd,

Authors:

Leslie New, PhD

Carl Donovan, PhD

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2 Integration of EE outcomes within overall Project

The expert elicitation has resulted in two key outcomes that can be used to inform ornithological assessments for offshore renewable energy developments:

1. The estimation of the potential displacement mortality rates affecting six species (common guillemot, razorbill, Atlantic puffin, black-legged kittiwake, northern gannet and red-throated diver) that currently need to be considered as part of the consenting process for off-shore windfarms in the UK. The estimates of displacement mortality rates were elicited both for individual birds in the breeding and non-breeding seasons (survival) and their dependents (breeding success) in the breeding season.

2. Identification of key processes, factors and information not currently accounted for within ornithological assessments for displacement impacts

In a separate report, the QuMR project team will outline how the elicited displacement mortality rates for a) birds in the breeding and non-breeding season and b) their dependents could be integrated into the current assessment process, with specific reference to the displacement mortalities' use within the displacement matrix. We will summarise the potential benefits from integrating the elicited values into the assessment process, particularly as it relates to more accurately representing the uncertainty within assessments for displacement impacts.

In addition, this report will summarise and set out high-level recommendations for how the key knowledge gaps identified during the EE process (2. above) could be addressed through either new science (data collection and analyses) or amendments to the assessment process.

3 Introduction

This workshop was focused on using expert elicitation to fill knowledge gaps related to the potential displacement mortality rate of seabirds in response to the presence of offshore wind farms. Expert elicitation is a formal, structured process designed to obtain experts' opinion and knowledge while reducing heuristics and biases (e.g., Tversky & Kahneman 1974) and accounting for the cognitive processes (e.g., Hogarth 1975) individuals use to interpret the information and questions with which they are presented. Another major component of the elicitation process is clear documentation of the methods and judgements to ensure transparency (Hemming et al. 2017; Gosling 2018). Expert elicitation has been used in numerous decision-making contexts, including geology (e.g., Aspinall 2006), cyber security risk (e.g., Cains et al. 2021), health (e.g., Knol et al. 2009), drug development (e.g., Dallow et al. 2018), and energy development (e.g., Usher & Strachan 2013), amongst others. There is also a growing use of the process in ecology and conservation, including within the marine environment (e.g., King et al. 2015, Nevalainen, Helle & Vanhatalo 2018). Expert elicitation helps inform several influential global policies as well, including the IUCN Red List and IPCC assessment (IUCN 2021; Mastrandea et al. 2010). As a result, it provides a valuable, established framework to help address some of the uncertainties associated with the potential displacement mortality in seabirds in response to offshore wind facilities.

The workshop was held as part of an Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind project that aims to provide ecologically and geographically informed species-level estimates of displacement mortality. The focus on displacement mortality comes from the Joint Statutory Nature Conservation Bodies (SNCB) Interim Displacement Advice Notice, which provides guidelines for how the assessment of the potential effects of offshore wind farm developments should be presented (Joint-SNCB 2022). Part of the requirements laid out in these guidelines requires assessments to assign a range of displacement levels to individual species and determine the rates of adult mortality associated with each level. These two metrics, displacement rate and displacement mortality rate, are then used to estimate potential displacement impacts, which are assessed at assumed levels from 0-100% at pre-defined intervals.

While there is some information in the scientific literature regarding displacement rates (e.g., Furness et al. 2013, Wade et a. 2016), there are significant knowledge gaps when it comes to displacement mortality rates (refer embedded document in section 11). Yet displacement mortality is an important part of the assessment process and can greatly influence the estimated effects of offshore wind farms on seabird populations. Furthermore, recent work with the individual-based model SeabORD (Searle et al. 2014, 2018) has indicated the potential for displacement mortality to be theoretically higher than those currently used in the existing assessment framework (the displacement matrix) (Searle et al 2020). Given that the values used within the displacement matrix were based on SNCB advice and assumed to be precautionary, the mismatch between the two approaches is of concern, albeit at a theoretical level.

When considering the effects of offshore wind in the UK, there are currently six main species of concern: the common guillemot (*Uria aalge*), razorbill (*Alca torda*), Atlantic puffin (*Fraturcula arctica*), black-legged kittiwakes (*Rissa tridactyla*), northern gannet (*Morus bassanus*) and red-throated divers (*Gavia stellata*). Two additional species are also of concern, Sandwich tern (*Thalasseus sandvicensis*) and lesser-black backed gull (*Larus fuscus*), but were not considered here due to needing to restrict the number of questions and parameters for which experts were asked to provide estimates. Given the uncertainty associated with displacement mortality in general, and for these species in particular, the workshop detailed in this report sought to address the knowledge gaps related to the excess mortality rates for these species, for both individual birds and their inter-dependents. With the exception of the red-throated divers, displacement mortality was also considered separately in the breeding and non-breeding season.

4 Expert Elicitation Workshop for Estimating the Displacement Mortality of Seabirds

4.1 Workshop Goals

The goal of the workshop was to address some of the uncertainty around the environmental impacts of offshore wind farms in the context of the UK North Sea. The workshop focused on the estimation of the potential displacement mortality rates affecting the common guillemot, razorbill, Atlantic puffin, black-legged kittiwakes, northern gannet and red-throated divers. The purpose of eliciting experts' judgements regarding these knowledge gaps was to gain a better understanding of the biological context in which displacement mortality may occur, and to provide information of relevance to the implementation of current assessment methodologies (Joint-SNCB 2022). More specifically, the workshop was intended to elicit information from the experts on:

- The biological processes relevant to the "mortality rate of displaced birds".
- The timescales over which the mortality rate of displaced birds are estimated.
- The precise definition of the "mortality rate of displaced birds".

As noted in the discussion with the experts, the scope of the workshop was limited to eliciting the displacement mortality rate related to an individual's interaction with a single offshore wind facility in either the breeding or non-breeding season. The cumulative effects of individuals interacting with multiple wind farms are accounted for separately within the assessment (through the summation of individual impacts) and was considered beyond the scope of the workshop. Furthermore, the workshop sought to elicit the best biological estimates of displacement mortality, rather than seeking to build a definition that was consistent with current approaches used within assessments (the displacement matrix for OWF consenting processes, and individual-based models such as SeabORD). How the experts' elicited values might be integrated into the assessment process was not a focus of the workshop.

The workshops were held virtually on 5th, 13th, 17th of May and 10th of June 2022. A list of workshop participants, expert statements and a copy of the agenda can be found in Appendices 8, 9 and 12.

4.2 Workshop Preparation

Preparation for the workshop required the identification and recruitment of experts to participate in the workshop. To help select relevant experts, ORJIP Offshore Wind and the project team identified the following areas of expertise as valuable for addressing the recognized knowledge gaps: offshore wind interactions with wildlife, seabird ecology and life history, particularly as relates to the species of interest, and familiarity with the UK assessment process.

In addition, participation from individuals from a variety of institutional backgrounds, including academia, research institutes, government, and non-profits was sought. Experts' nationality and location was only considered inasmuch as to how the time zone in which an individual resided may affect their ability to take part in the workshop, given its virtual nature. However, this criterion was not used to exclude experts from the workshop. If an invited individual was unable to attend, they were asked if they would be willing to provide the names of alternate individuals with similar expertise. This aids in the inclusion of a wider range of experts, and expertise, then would otherwise have been available. A complete list of experts who took part in the workshop, their expertise and affiliation, can be found in Appendix section 8.

An evidence dossier (Appendix section 11) was compiled for the experts to provide them with a precis of the information currently available regarding seabird interactions with offshore wind and any evidence for resultant displacement mortality. This included a review of the displacement rates and displacement mortality rates currently used in assessments for red-throated divers, auks, gannets and gulls, a review of processes which may affect displacement mortality rates, including carry over effects, habitat quality, density dependence and seasonal effects, and a review of the tools and methods used for estimating mortality rates (the displacement matrix and SeabORD). Providing the dossier to experts in advance of the workshop ensures that all individuals have access to the same information and helps build a common understanding of problem at hand (Dallow et al. 2018). It also provides the baseline from which the experts can consider whether any key information was missed, a question which they were asked explicitly as part of Expert Enquiry form (see Appendix section 8).

The experts are requested to fill out the Expert Enquiry form in advance of the workshop not only to identify additional information, but also to ensure that the experts' affiliation, expertise and declarations of interest are recorded correctly (Oakley & O'Hagan 2019).

4.3 Background Presentations

A series of presentations (Table 1) were given on the first and second days of the workshop to supplement the information provided to the experts in the evidence dossier (Appendix section 11) and to provide training in making probabilistic judgements.

Table 1. Details of presentations made at the May 5th and 13th workshops.

Presenter	Information presented
Kate Searle & Adam Butler	Current practice for UK assessments of seabird displacement impacts
Leslie New	Approach to Elicitation
Leslie New	Introduction to Expert Elicitation
Leslie New	Making Probabilistic Judgements

4.4 Elicitation of Displacement Mortality

The expert elicitation was conducted using the Sheffield Elicitation Framework (SHELF V4.0) (O'Hagan et al. 2006), which is described in detail in Appendix section 10. The quantile method was used for all the elicitation questions, in which experts were first asked to provide a lower and upper plausible bound for the quantity of interest (X), such that it is unlikely, although not impossible, that X would fall outside the defined range. They were then asked to provide a median value (M), which is a value such that X is as equally likely to be below M as above M. Lastly, experts were asked to define the lower and upper quartiles, which are also known as the first and third quartiles, respectively. For the lower quartile, this requires the experts to choose a value that divides the range from the lower plausible bound to M into two equally likely ranges of values for X. The same process is used for the upper quartile, except that the experts must split the range from M to the upper plausible bound into two equally likely ranges of values for X.

The SHELF software (Oakley 2020), which is used in conjunction with the statistical computing program R (v. 4.1.0, R Core Team 2021), fits statistical distributions to the experts' elicited judgements using a least squares procedure (Oakley & O'Hagan 2019). The density functions are fitted excluding the information on the lower and upper plausible bounds but are then truncated at these limits for plotting and any use in future analyses.

A total of 9 experts took part in the elicitation process (see Appendix section 12). Participants were made aware that a written record would be made of the elicitation, and would be available as part of this Report (Appendices 13) so as to ensure an open and transparent process.

In addition, over the course of the workshops, there were a total of 17 unique observers to the process (see Appendix section 12). These were individuals from government agencies, research groups and industry who were interested in observing the process, as they are involved in development, management and policy making related to offshore wind. While these individuals were allowed to observe the elicitation, they did not take part, and could only communicate with the experts through the facilitator. The experts were fully aware of the observers' presence, although they were not visible on the remote platform, and in private discussion agreed that the presence of the observers would not influence their contributions to the elicitation process.

4.4.1 Approach to Elicitation

Given the virtual nature of the workshop, it was split into four three-hour sessions, each separated by at least three days and split into distinct segments (see Appendix section 9 for the agenda), with a remote component to the elicitation process occurring in between. The aim of this structure was to maximize the experts' engagement while minimizing the time spent in an on-line platform.

On Day 1 (5th May) the information provided to the experts as part of the evidence dossier was supplemented with presentations on the assessment process, focusing on the displacement matrix and the individual-based model SeabORD (see Section 2.3). This provided experts the opportunity to discuss the information amongst themselves, bring to light data that were not included in the evidence dossier and to ask questions of the project team and the other experts. As part of these discussions, it was determined that the focus of the elicitation would be on eliciting the best biological information and definition of displacement mortality rates, as opposed to one that fitted with the more technical requirements of the displacement matrix. The experts were also presented with an initial definition for displacement mortality rate, and worked to clarify the wording to ensure that everyone shared a similar understanding of what was being asked. No values were elicited from the experts on Day 1.

On Day 2 (13th May) the experts were presented with greater details of the elicitation process, as well as training in making probabilistic judgements. Additional discussion occurred regarding the biological processes relevant to displacement mortality, and it was determined that not only was there the potential for seasonal differences (breeding versus non-breeding seasons), but also that an individual's displacement would potentially affect the mortality of their dependents, as well as their own. This led to the experts agreeing to following definition of the value of interest for this elicitation:

- Displacement mortality rate: The excess mortality rates (as an absolute %) for an individual bird or their dependents that would have used the area of influence of the offshore wind farm and associated infrastructure if there had been no offshore wind farm, but which is displaced away from the area during construction and/or operation.

Therefore, for the common guillemot, razorbill, Atlantic puffin, black-legged kittiwakes and northern gannet the experts were tasked with answering three questions for each species: displacement mortality rate for the individual in the non-breeding season, displacement mortality rate for the individual in the breeding season, and displacement mortality rate of the individual's dependents in the breeding season. For red-throated divers, only one question was asked regarding displacement mortality rate because in the context of the UK, this species is only affected in the non-breeding season. This led to a total of 16 values to be elicited.

The detailed discussions and modifications to the definition of displacement mortality rate, and the resulting increase in the number of questions to be asked, reduced linguistic ambiguity, and thus improved the elicitation process.

No values were elicited from the experts during Day 2 of the workshop. Instead, experts were asked to do the first round of the elicitation remotely, providing their answers to the facilitation team prior to Day 3. The quantile method was used to elicit the quantities of interest. To aid experts in visualizing the range of values and weight of belief, each question included a link to a Shiny app (Chang et al. 2022) that created a boxplot based upon their submitted values (Figure 1). The app also gave the experts the ability to download their judgments in a .csv file automatically formatted to be used in the subsequent analysis and plotting of the experts' probability distributions. The experts' names were requested as part of the process so that the facilitation team could be assured that all experts answered the question, but all results were anonymized prior to presentation to the experts or inclusion in the report.

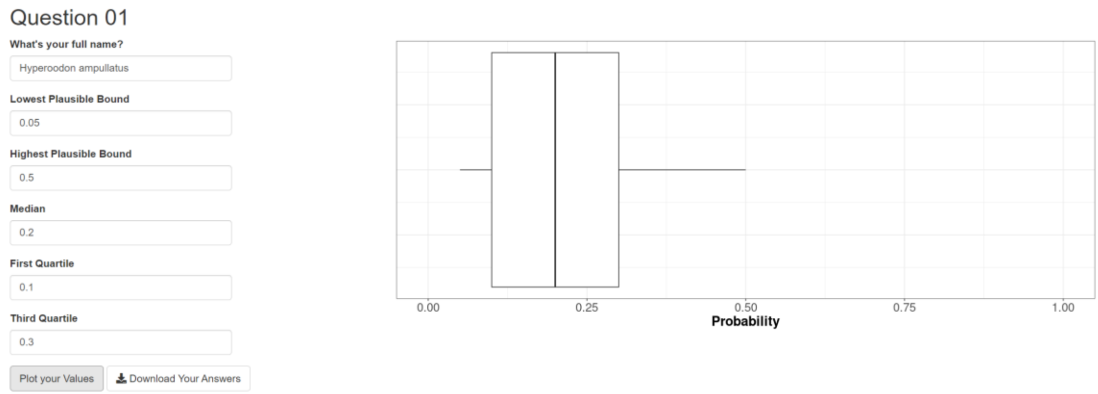

Figure 1: Example of the Shiny app used by experts to answer the elicitation questions, with hypothetical values included to demonstrate the boxplot generated based on the submitted bounds and quantiles.

On Day 3 (17th May) the experts were shown the resulting probability distributions for the first round of the elicitation (see section 5 for indicative outputs). During discussions experts were asked to share any additional evidence, their thought processes in answering the question and consider the differences in the elicited values and provide plausible biological mechanisms by which they might arise. This discussion is a key component of the elicitation process, as it has been shown to result in improvements in response accuracy (Hanea et al. 2016). The experts were provided with the opportunity to revise and resubmit their judgements elicitation remotely, providing them to the elicitation team prior to Day 4.

On Day 4 (10th June) the elicited second round of distributions were reviewed again, and any additional discussion or modifications made before the experts determined whether the resulting distributions were an accurate reflection of their beliefs and the discussions that were held during the workshops. Very few revisions of parameters were provided by the experts who had previously submitted figures, and they were minor changes. One expert provided previously missing tables of estimates.

For additional details of the SHELF elicitation process, please see Appendix 3 – Elicitation Process.

4.4.2 Fitting distributions to experts' estimates

The EE process elicits distributions for the values of interest from the experts, which are represented by 5 reference points, the minimum and maximum plausible values and the 25th, 50th, and 75th percentiles, i.e., the quartiles of a probability distribution. The five values elicited from the experts for each question are presented in section 5.

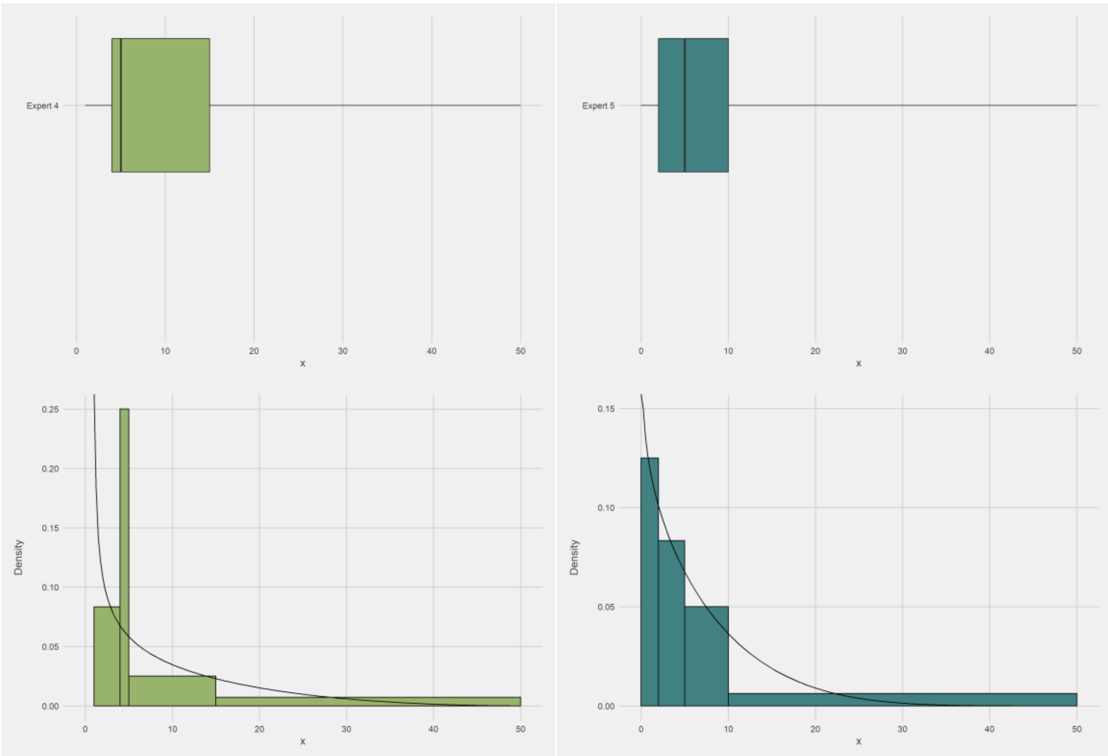

Figure 2: Responses from example experts presented as density plots. Each histogram bar represents where an expert has placed 25% of their belief, and therefore define the quartiles as well. The super-imposed lines are the fitted density functions.

The expert's values are frequently used in a Monte-Carlo fashion in subsequent analyses. While the specific implementation will depend on the analysis required, Monte Carlo in this context typically refers to randomly sampling from the experts' raw summary distributions or from distributions fitted to the experts' summary statistics. Note the elicitation process does not explicitly solicit the fine-scale shape of the distributions for the values of interest.

In sections 5.2 to 5.4 parametric distributions have been fitted to the expert's values, using the SHELF methodology and tools (Oakley, 2021), whereby a range of distributions are fitted, with the best of these chosen by an objective measure. Example individual fitted curves are given separately in Figure 3, but are combined when presenting the experts' judgements.

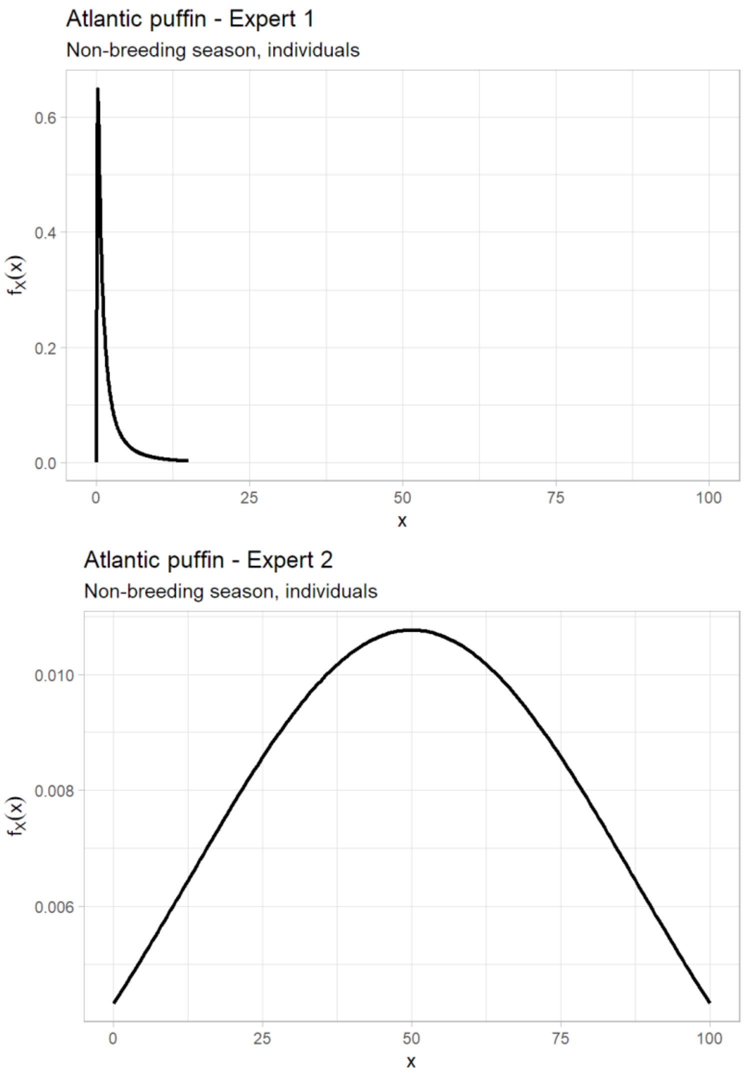

Figure 3: example individual distributions fitted to expert's elicited values, noting the y-axis is not a fixed common scale. These are examples of the underpinnings of the following figures, where all expert's curves are presented together. The exact distributions and their fitted parameters for all individual curves are given in Table 8 to Table 20.

The fitted curves presented in this report could be used directly for simulation purposes, but it should be noted that other models could be validly used. In this regard, the following fitted curves are examples, with utility, but the fundamental elicitation outputs are those presented in the tables of the experts' estimates.

4.4.3 Collective expert curves

Also presented in the section 5 results are pooled curves for all experts combined, e.g., Figure 7. In these cases, an equally weighted linear pooling of the experts is provided to provide a summary distribution of the overall belief in the parameter value. Although it is not prescribed how the elicitation results might be used in subsequent assessments, this pooled curve gives a view of the aggregate belief of the experts.

5 Elicitation outputs

This section presents the five reference points obtained from the experts during the elicitation process, summary plots, fitted curves for each expert, and pooled distributions for all experts combined.

5.1 Observations on results

Although there is substantial detail and information within the results of each question posed to, and answered by, the experts, some broad observations can be made:

- The bulk of belief for the Displacement Mortality Rates (DMR) for individuals (breeding or non-breeding season) is on values below 10%. There was, however, notable variance in the estimated upper bounds, meaning disagreement and overall uncertainty in what would be a plausible upper limit to the effects of OWF in terms of DMR.

- In terms of the effects on dependents, there was markedly less agreement and certainty indicated by the experts' responses. However, overall, the DMR for dependents was estimated as being substantially greater than for the mature individuals.

5.2 Displacement mortality for individuals in the non-breeding season

It should be noted that these estimates are based on opinions of the experts consulted, not empirical data. Wherever feasible, research should be undertaken to provide data driven estimates of the quantity of interest.

The experts were asked to provide a set of values that would answer the following question:

> *The excess mortality rates (as an absolute %) for an individual bird that would have used the area of influence of the OWF and associated infrastructure if there had been no OWF, but which is displaced away from the area during construction and/or operation.*

Figure 26 shows the statistical distributions chosen by each of the experts, which are summarized here by fitted density functions, using the tools and selection criteria with the SHELF R package (Oakley, 2021). Detailed expert-level outputs are presented, including the raw values from which alternative functions might be fitted.

5.2.1 Atlantic Puffins - Non-breeding Season, Individual Birds

Table 2: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality).

Question 9					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.50	1.0	2	3
Expert 2	0.01	0.25	0.5	2	20
Expert 3	0.00	3.00	6.0	25	40
Expert 4	1.00	2.00	3.0	7	15
Expert 5	0.00	0.50	1.0	3	15
Expert 6	0.00	25.00	50.0	75	100
Expert 7	0.00	1.00	2.5	3	5

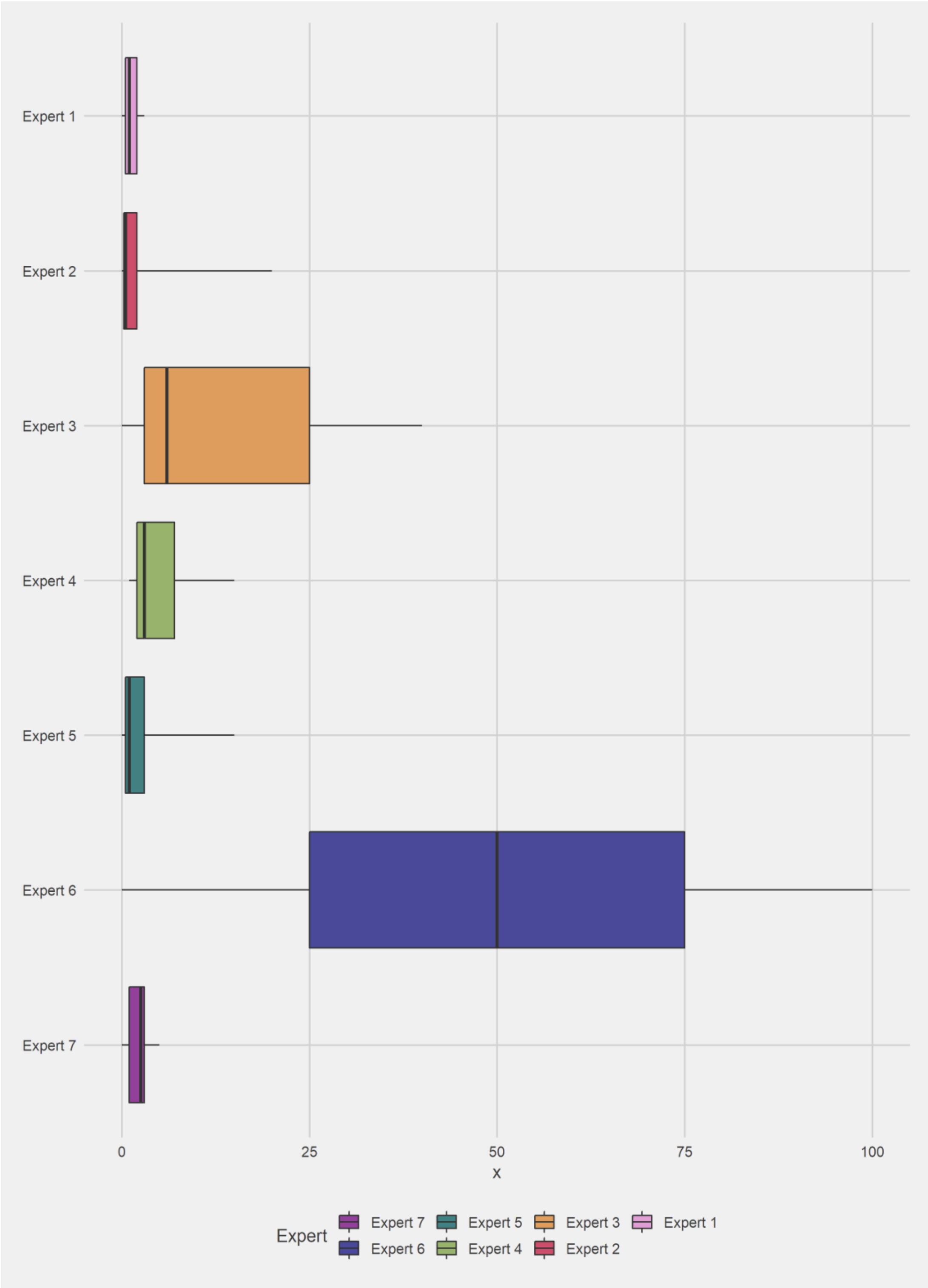

Figure 4: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

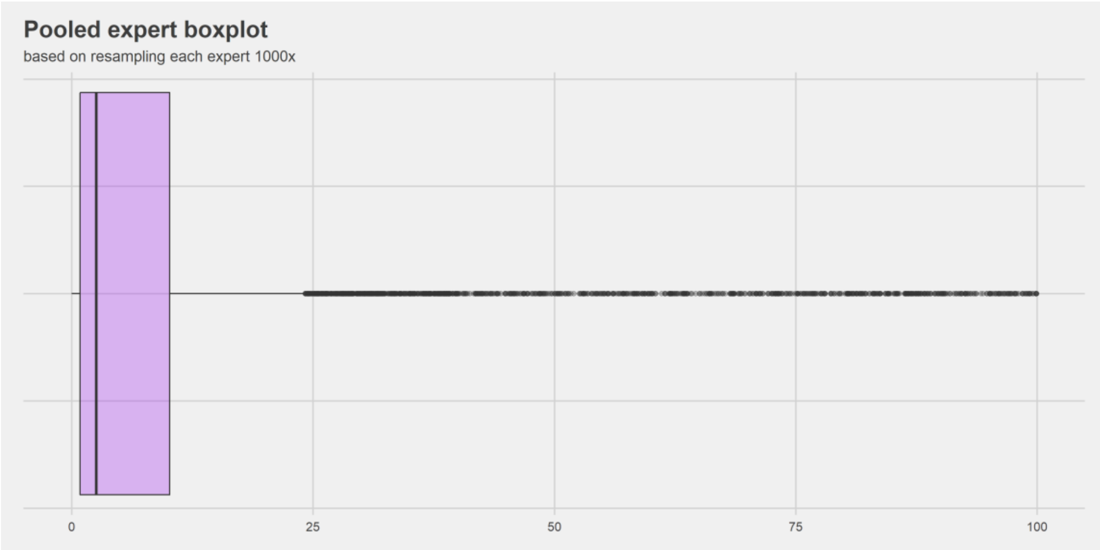

Figure 5: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

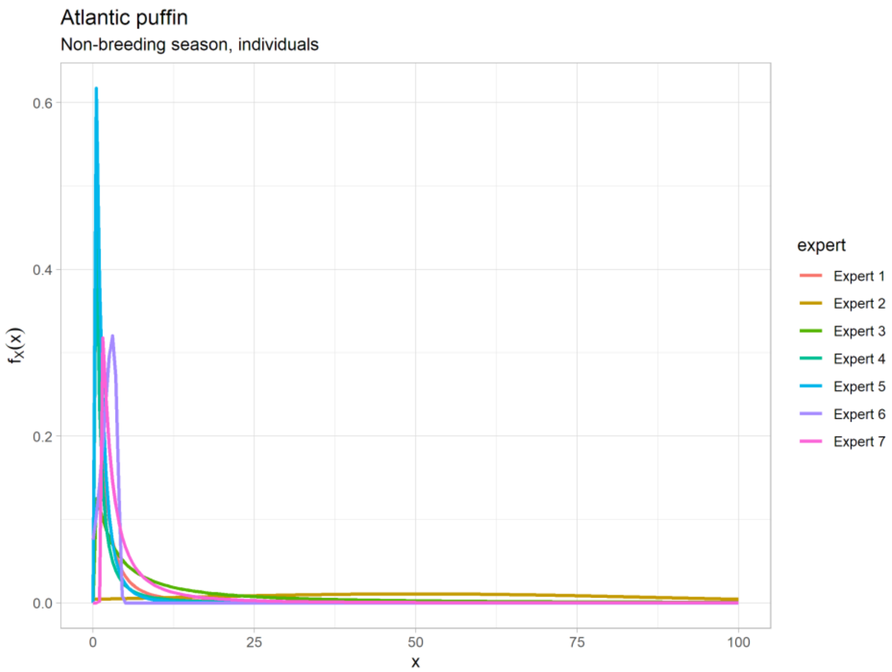

Figure 6: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

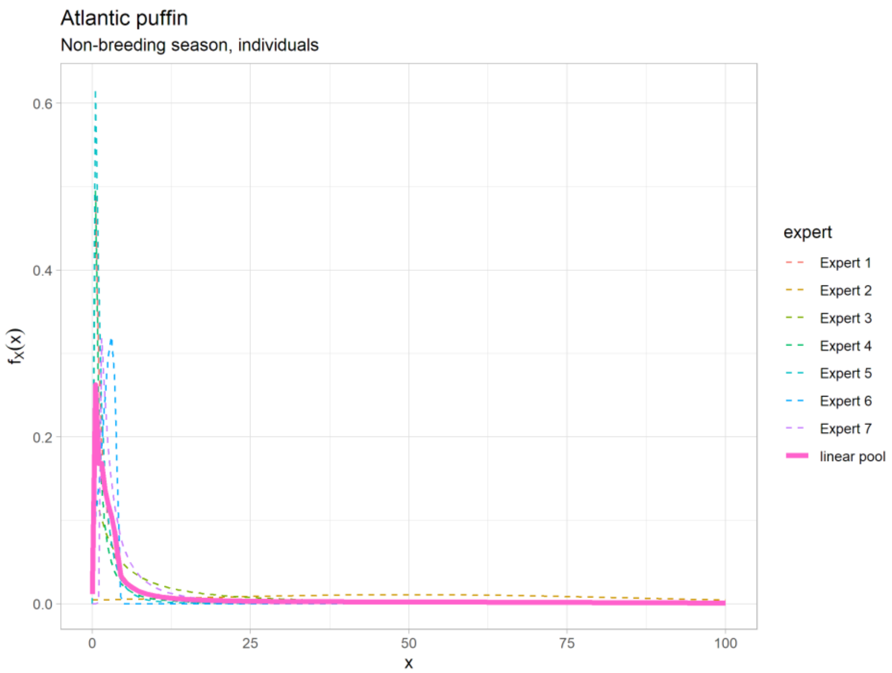

Figure 7: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.2.2 Guillemots - Non-breeding Season, Individual Birds

Table 3: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 3					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	3.00	6.0	8	12
Expert 2	0.00	0.50	1.0	2	3
Expert 3	0.00	2.50	5.0	20	30
Expert 4	0.01	0.25	0.5	2	20
Expert 5	0.00	0.50	1.0	3	15
Expert 6	0.00	25.00	50.0	75	100
Expert 7	1.00	3.00	6.0	20	40

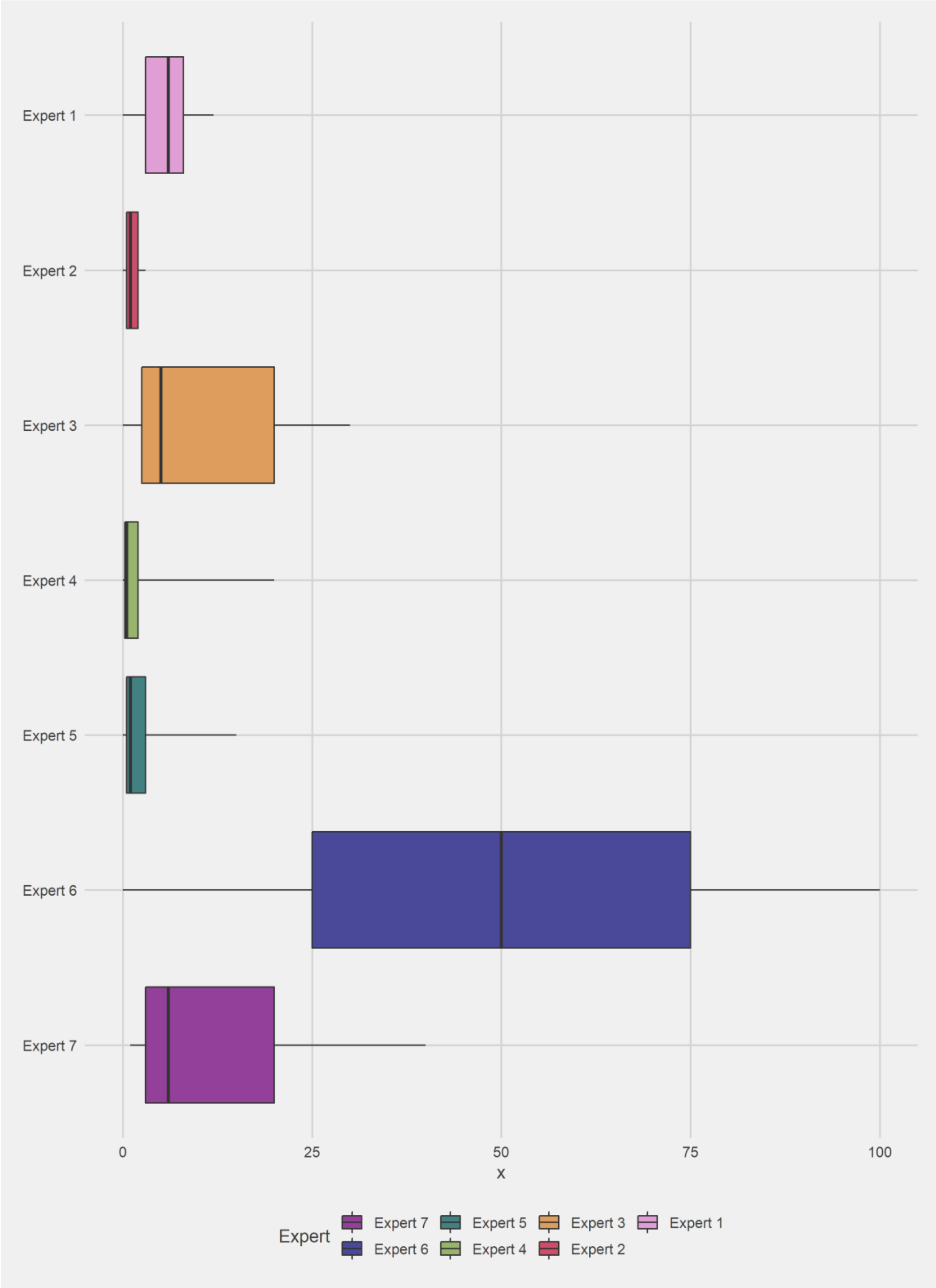

Figure 8: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

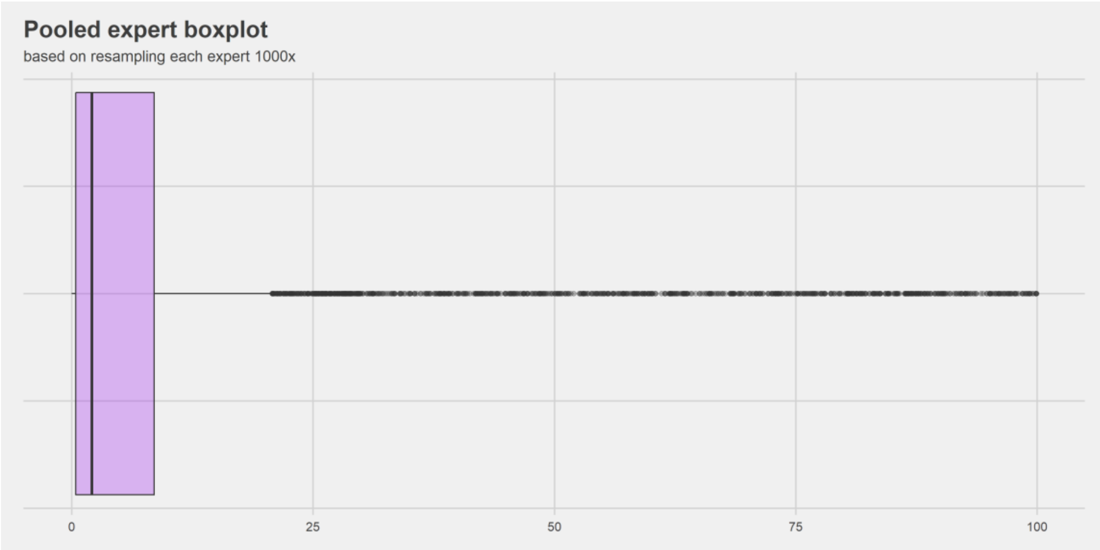

Figure 9: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

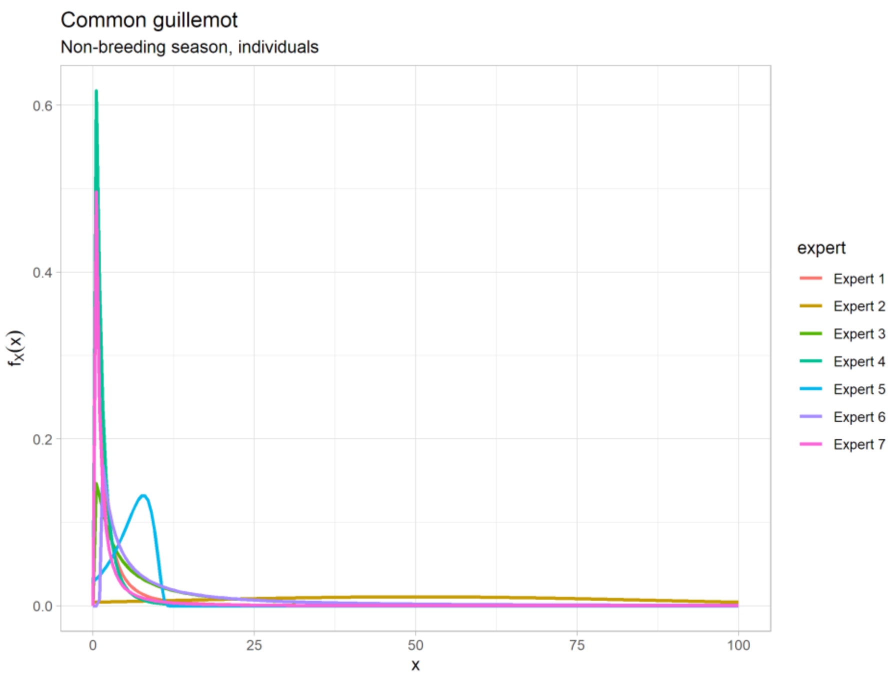

Figure 10: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

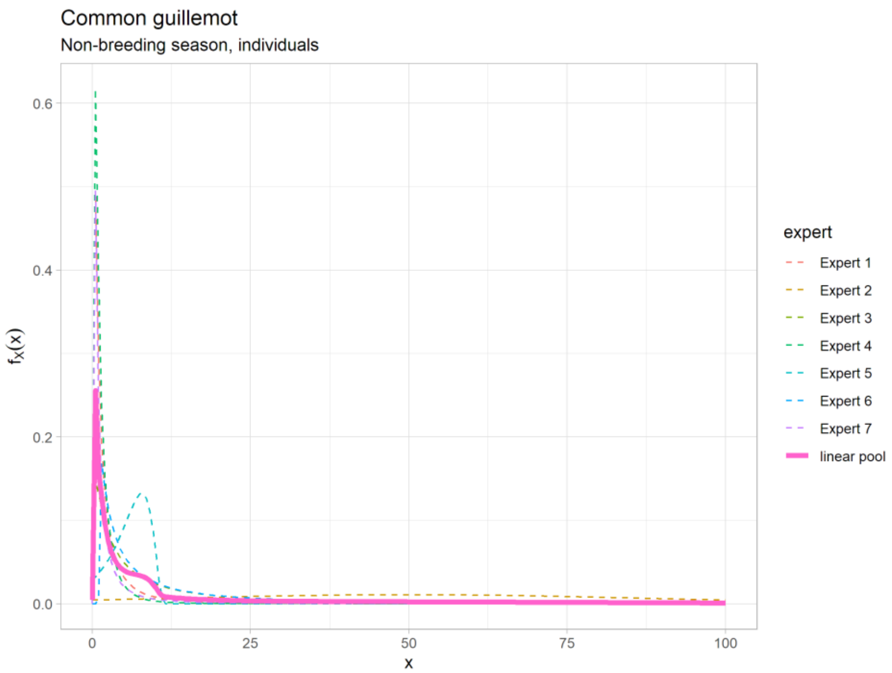

Figure 11: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.2.3 Black-legged kittiwakes - Non-breeding Season, Individual Birds

Table 4: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 12					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.1	0.2	0.3	1
Expert 2	0.01	0.5	1.0	4.0	40
Expert 3	0.00	3.0	6.0	25.0	40
Expert 4	1.00	3.0	5.0	10.0	15
Expert 5	0.00	1.0	2.0	5.0	20
Expert 6	0.00	25.0	50.0	75.0	100
Expert 7	0.00	4.0	7.5	10.0	15

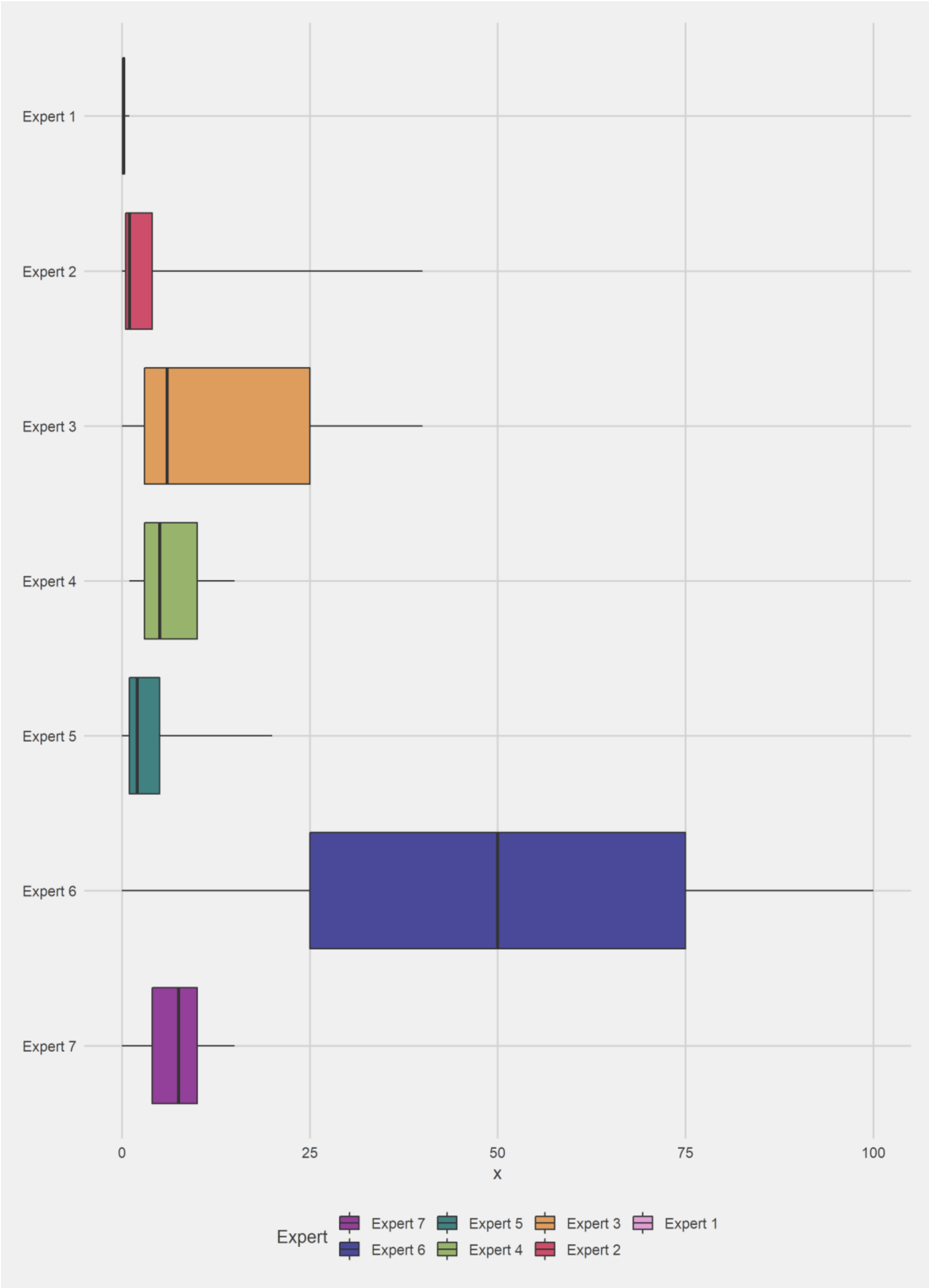

Figure 12: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

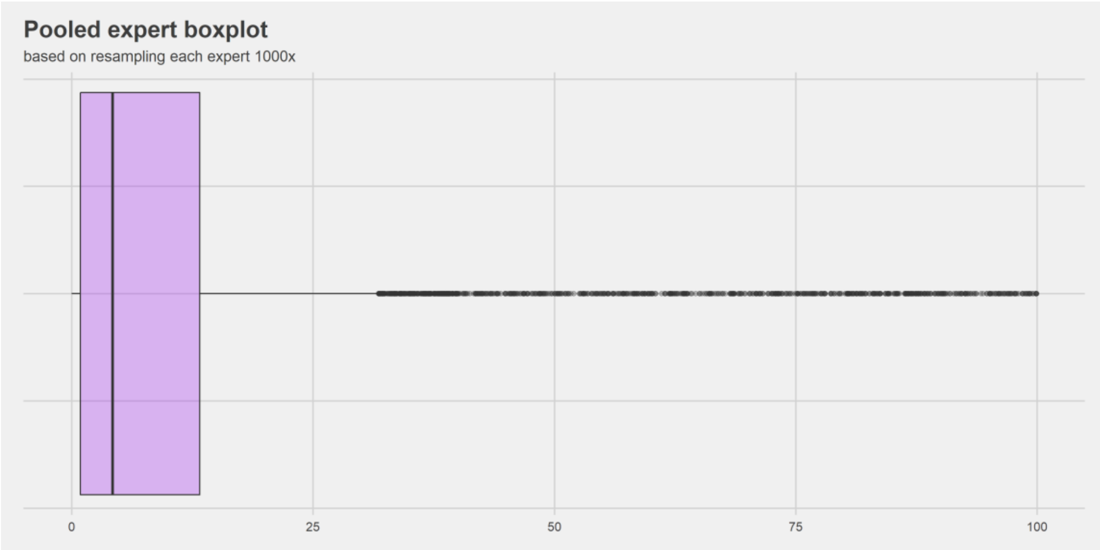

Figure 13: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

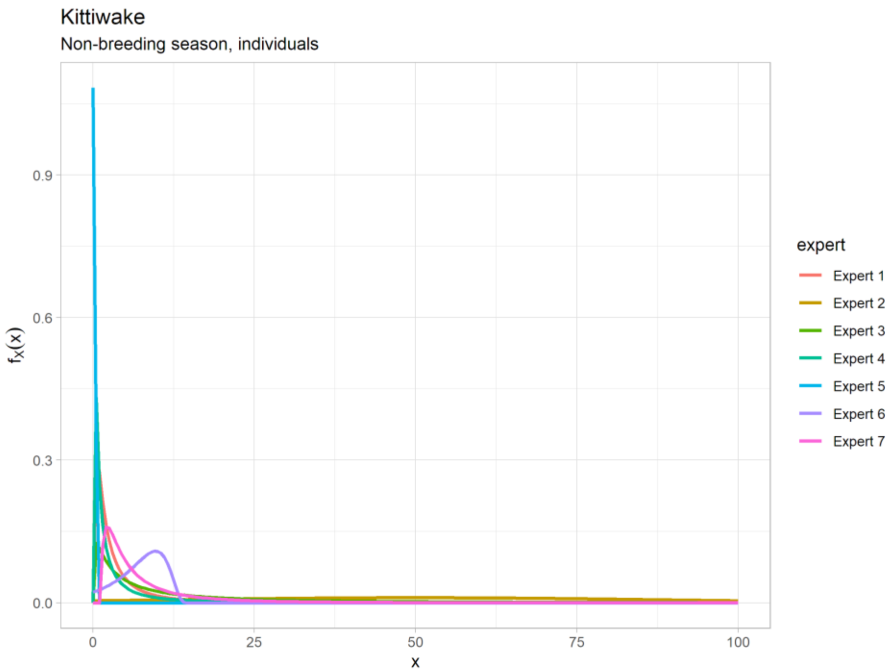

Figure 14: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

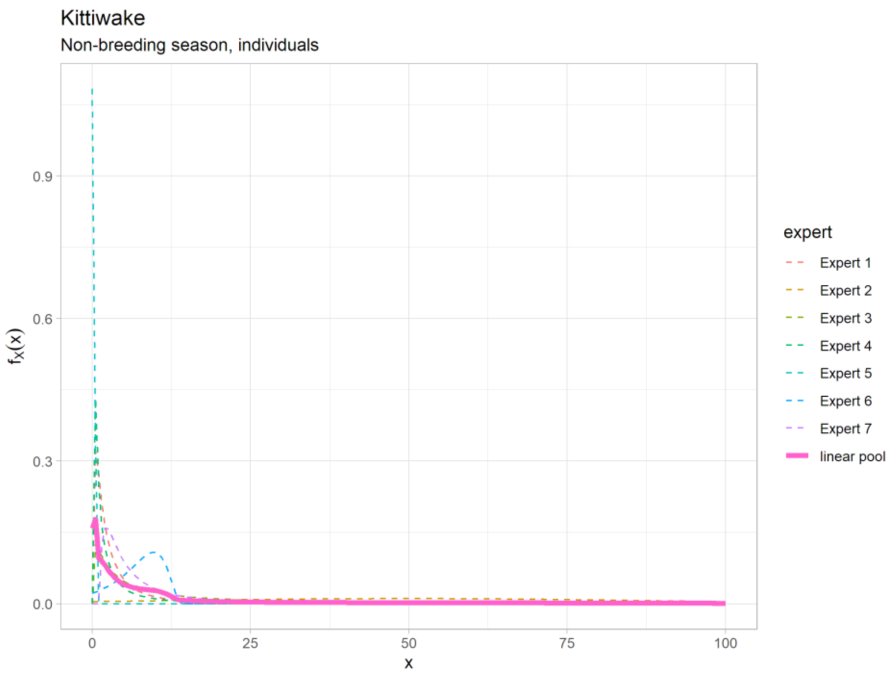

Figure 15: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.2.4 Northern gannets - Non-breeding Season, Individual birds

Table 5: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 15					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.100	0.20	0.3	1
Expert 2	0.01	0.125	0.25	1.0	10
Expert 3	0.00	1.000	2.00	10.0	30
Expert 4	1.00	3.000	7.00	14.0	20
Expert 5	0.00	0.500	1.00	3.0	10
Expert 6	0.00	25.000	50.00	75.0	100
Expert 7	0.00	1.000	2.50	3.0	5

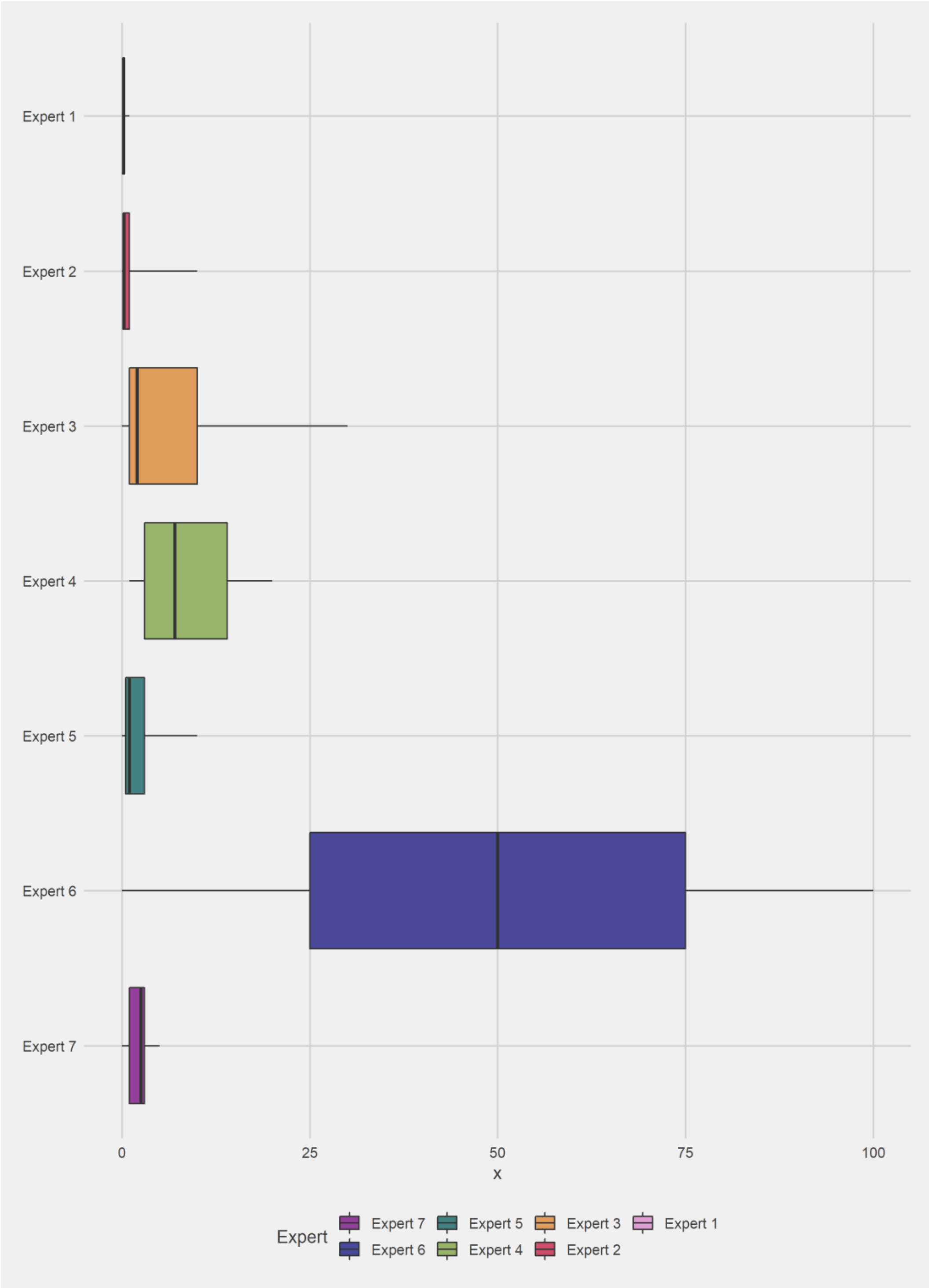

Figure 16: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

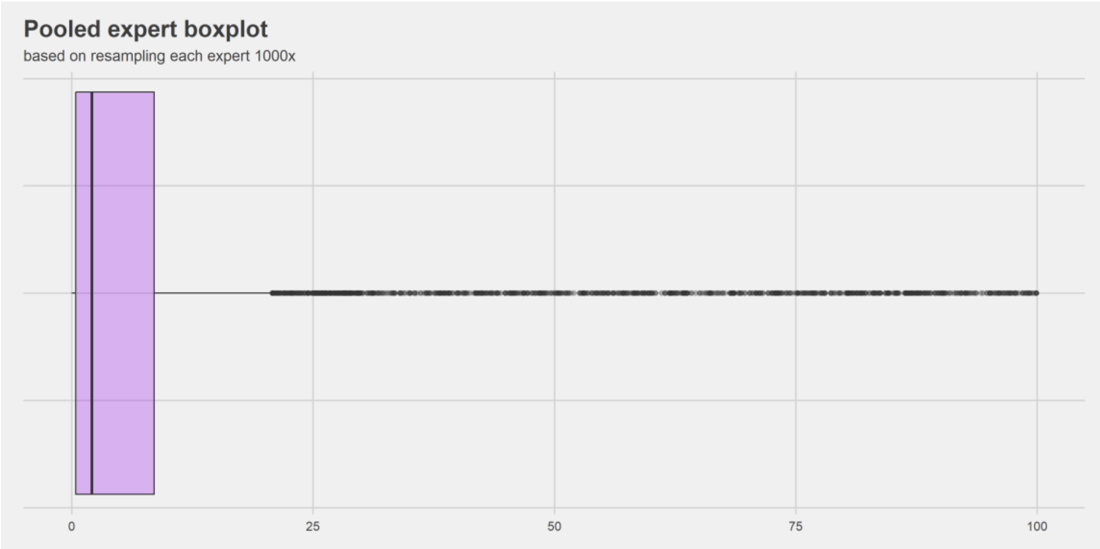

Figure 17: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

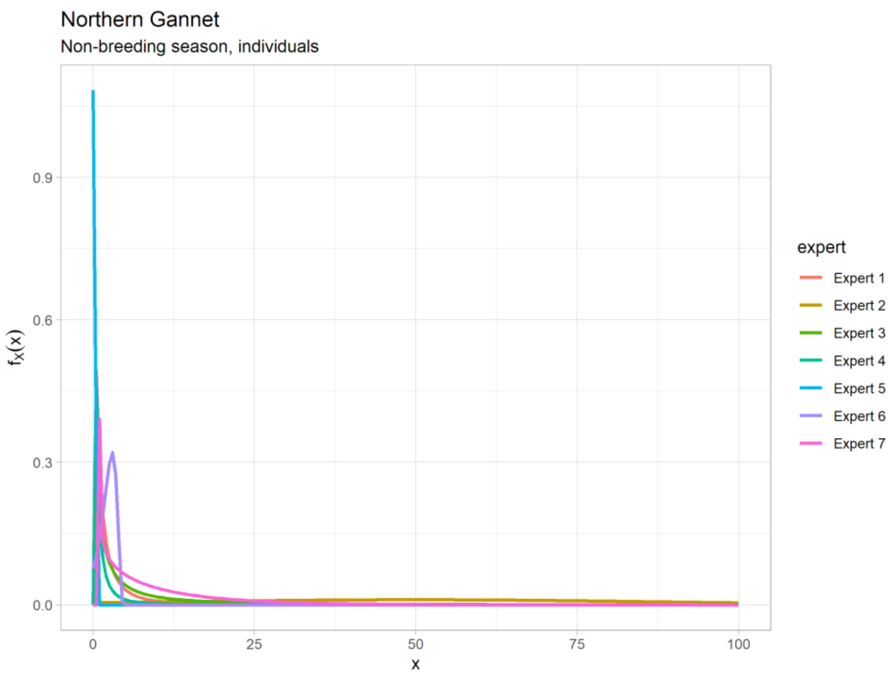

Figure 18: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

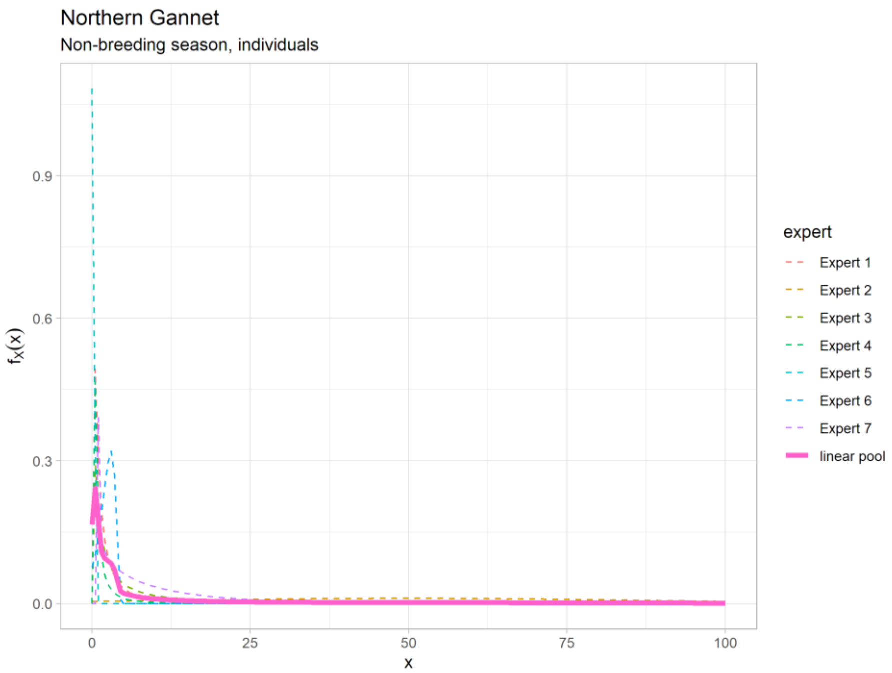

Figure 19: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.2.5 Razorbills - Non-breeding Season, Individual Birds

Table 6: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 6					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.50	1.0	2	3
Expert 2	0.01	0.25	0.5	2	20
Expert 3	0.00	2.50	5.0	20	30
Expert 4	1.00	3.00	5.0	8	15
Expert 5	0.00	0.50	1.0	3	15
Expert 6	0.00	25.00	50.0	75	100
Expert 7	0.00	5.00	11.0	14	22

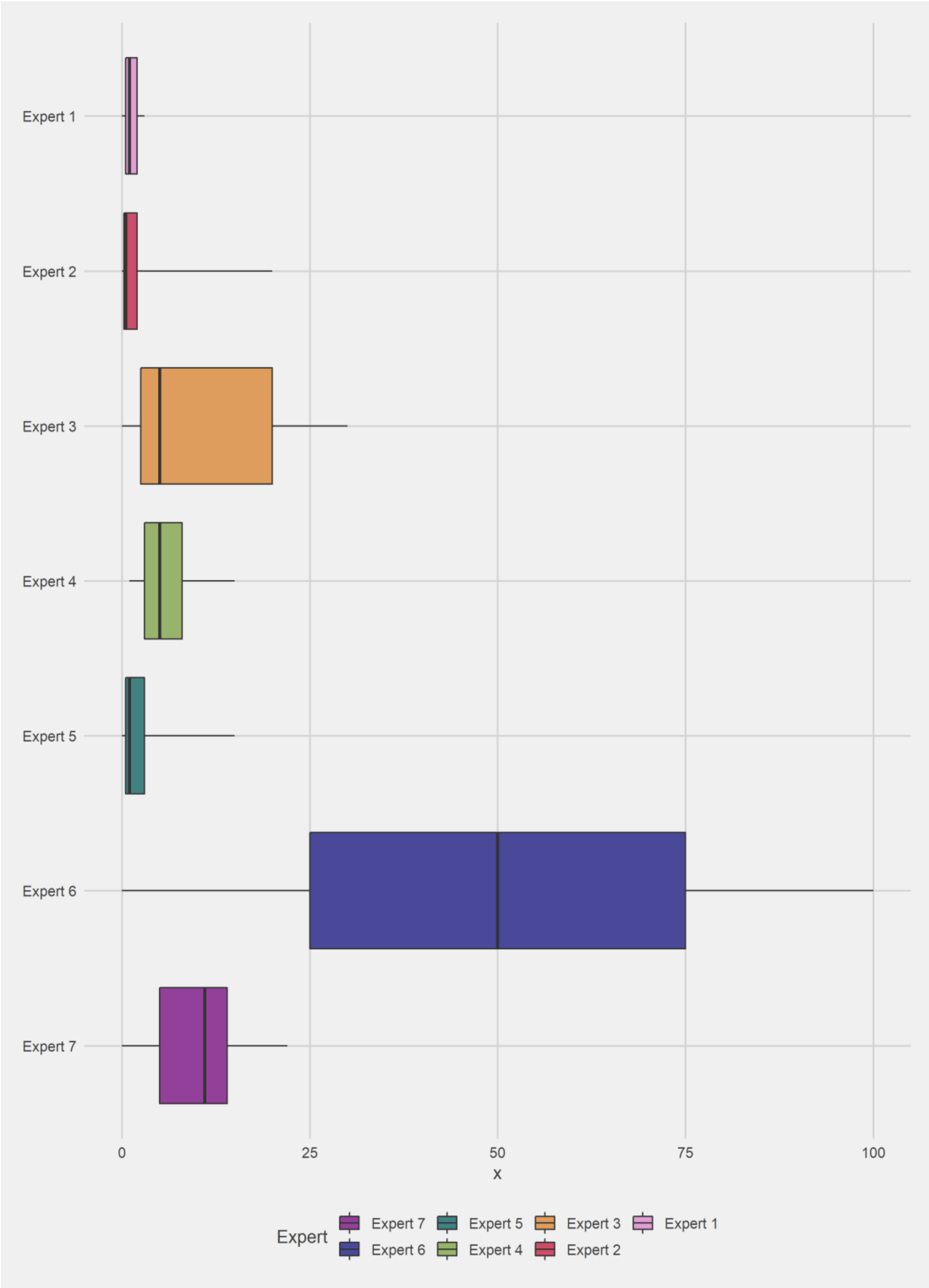

Figure 20: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

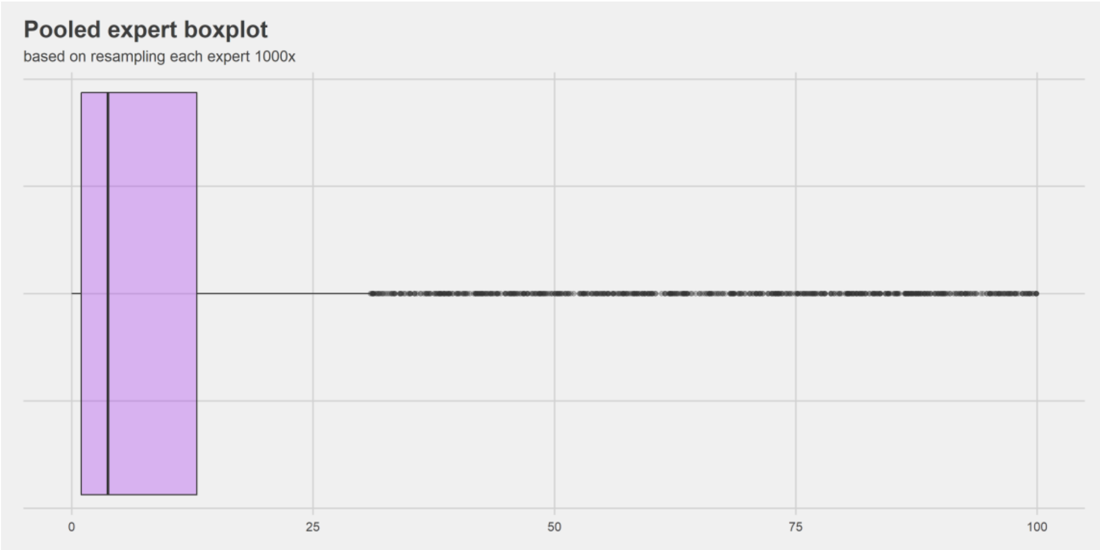

Figure 21: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

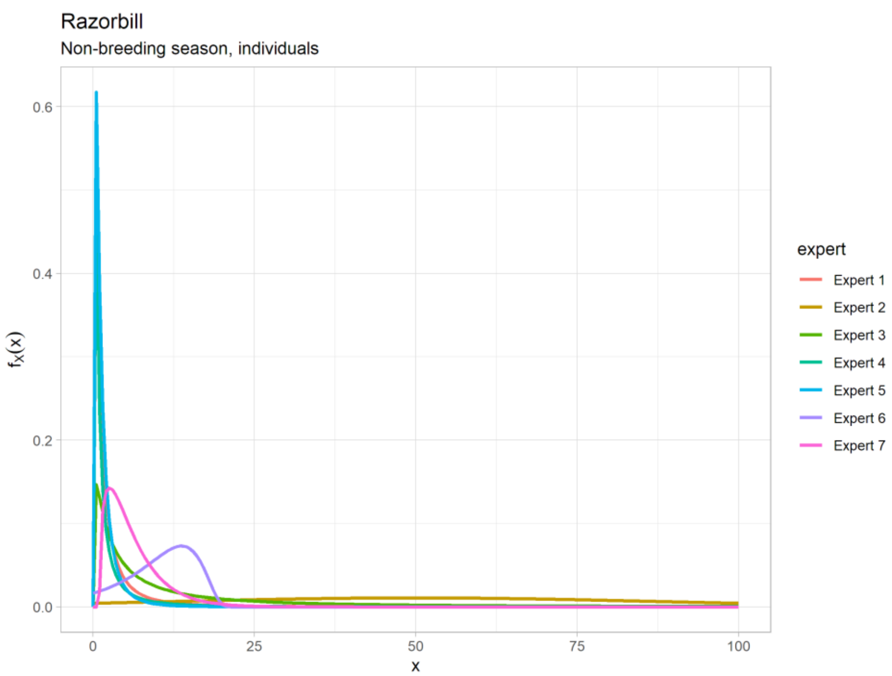

Figure 22: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

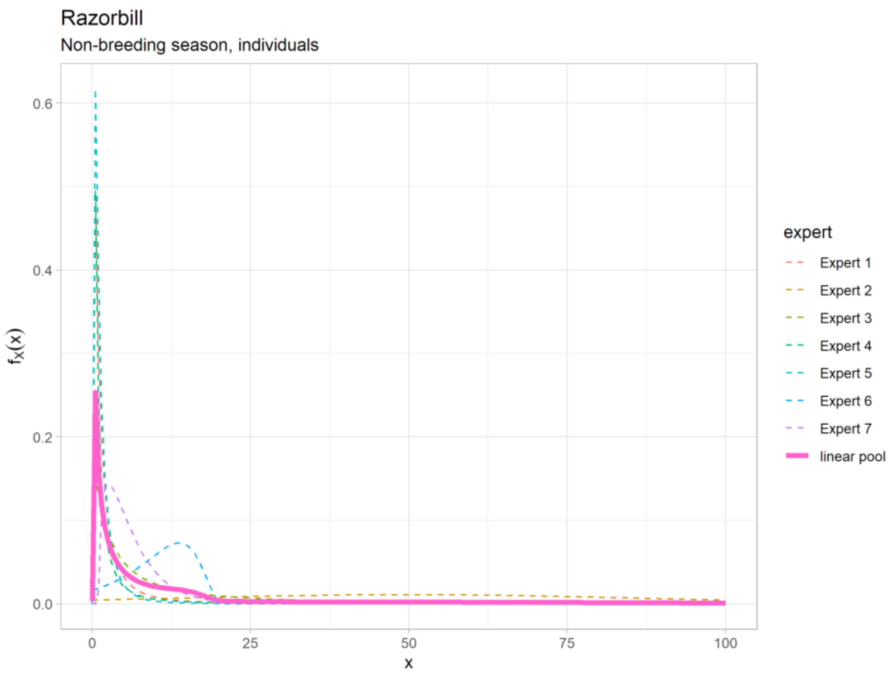

Figure 23: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.2.6 Red-throated divers - Non-breeding Season, Individual Birds

Table 7: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 16					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	1.0	2	3	10
Expert 2	0.01	0.5	2	8	40
Expert 3	0.00	3.0	6	25	40
Expert 4	5.00	8.0	15	25	40
Expert 5	0.00	1.0	2	5	20
Expert 6	0.00	25.0	50	75	100
Expert 7	0.00	8.0	16	20	32

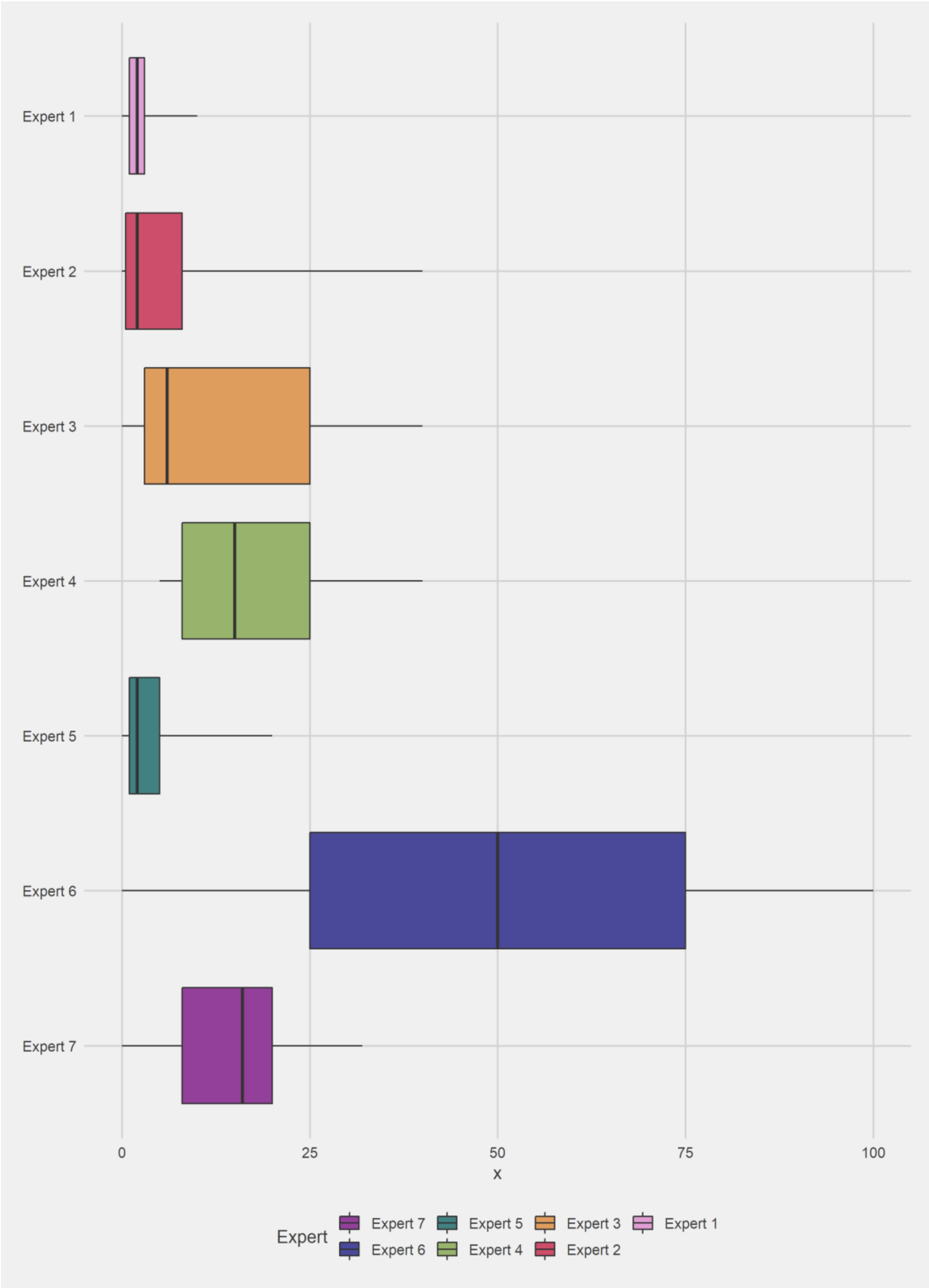

Figure 24: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

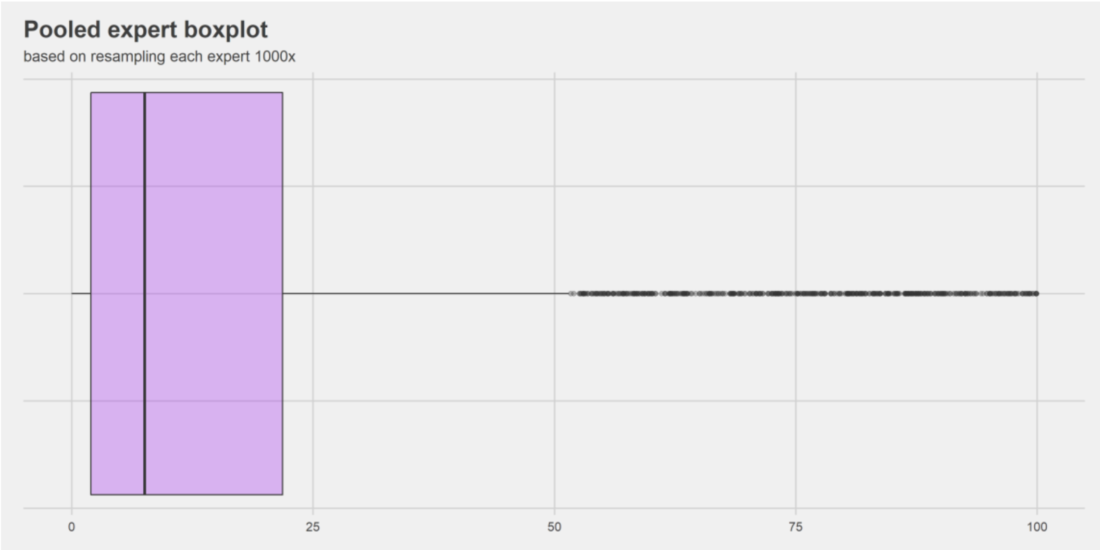

Figure 25: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

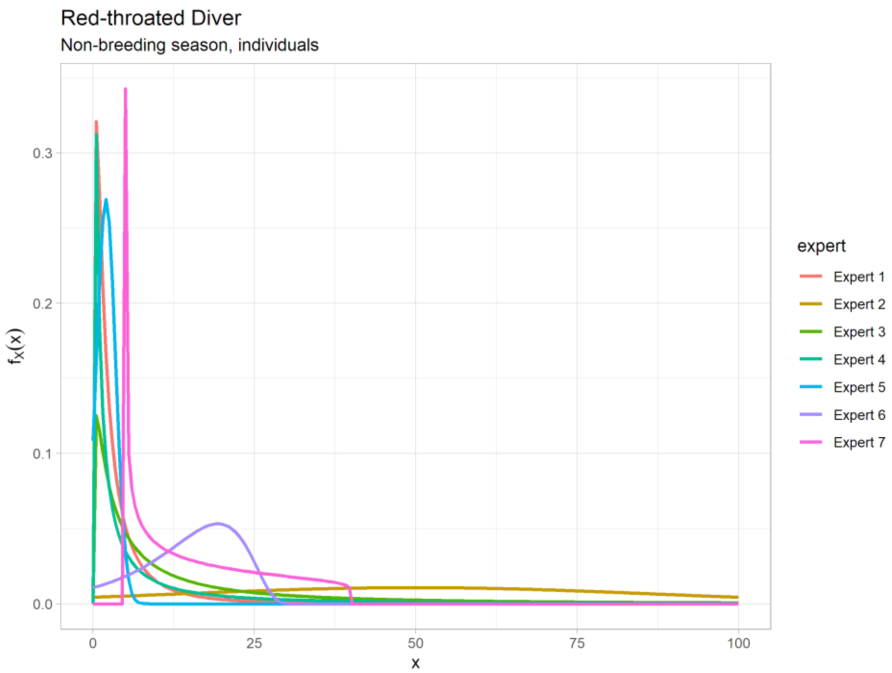

Figure 26: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

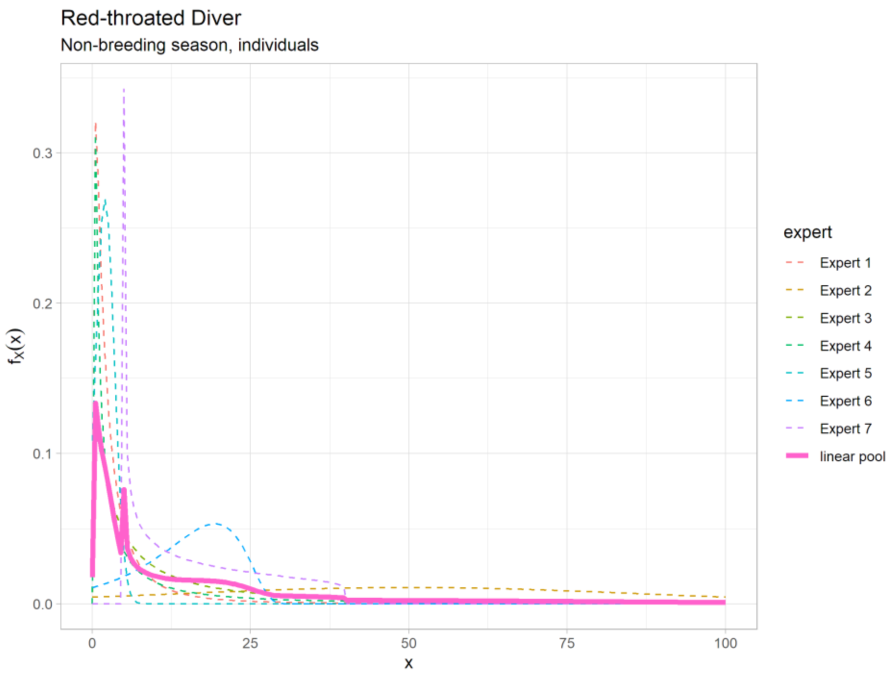

Figure 27: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

Table 8: Best fitting distribution and its parameters for each expert for each of the questions. "Best" in this context are by objective selection via the SHELF methodology and tools (Oakley, 2021).

		Non-breeding season, individuals		
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Atlantic puffins	Expert A	lognormal	0.115	1.35
	Expert B	normal	50	37.065
	Expert C	lognormal	2.002	1.632
	Expert D	lognormal	-0.517	1.621
	Expert E	lognormal	0	1.028
	Expert F	mirrorlognormal	0.987	0.535
	Expert G	lognormal	0.808	1.35
	Expert A	lognormal	0.115	1.35

Non-breeding season, individuals				
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Common guillemot	Expert B	normal	50	37.065
	Expert C	lognormal	1.808	1.596
	Expert D	lognormal	0	1.028
	Expert E	mirrorlognormal	1.792	0.601
	Expert F	lognormal	1.727	1.687
	Expert G	lognormal	-0.517	1.621
Kittiwake	Expert A	lognormal	0.756	1.2
	Expert B	normal	50	37.065
	Expert C	lognormal	2.002	1.632
	Expert D	lognormal	0.188	1.609
	Expert E	normal	0.2	0.148
	Expert F	mirrorlognormal	2.009	0.585
	Expert G	lognormal	1.419	1.117
Northern Gannet	Expert A	lognormal	0.115	1.35
	Expert B	normal	50	37.065
	Expert C	lognormal	0.958	1.794
	Expert D	lognormal	-1.232	1.647
	Expert E	normal	0.2	0.148
	Expert F	mirrorlognormal	0.987	0.535
	Expert G	gamma	0.776	0.081
Razorbill	Expert A	lognormal	0.115	1.35
	Expert B	normal	50	37.065
	Expert C	lognormal	1.808	1.596
	Expert D	lognormal	-0.517	1.621

Non-breeding season, individuals				
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
	Expert E	lognormal	0	1.028
	Expert F	mirrorlognormal	2.431	0.563
	Expert G	gamma	1.438	0.281
Red-throated Diver	Expert A	lognormal	0.756	1.2
	Expert B	normal	50	37.065
	Expert C	lognormal	2.002	1.632
	Expert D	lognormal	0.685	2.069
	Expert E	normal	2	1.483
	Expert F	mirrorlognormal	2.806	0.518
	Expert G	beta	0.595	1.108

5.3 Displacement mortality for individuals in the breeding season

The experts were asked to provide a set of values that would answer the following question:

> *The excess mortality rates (as an absolute %) for an individual bird that would have used the area of influence of the OWF and associated infrastructure if there had been no OWF, but which is displaced away from the area during construction and/or operation.*

Figure 34 to Figure 46 show the statistical distributions chosen by each of the experts, which are summarized here by fitted density functions, using the tools and selection criteria with the SHELF R package (Oakley, 2021). Detailed expert-level outputs are presented, including the raw values from which alternative functions might be fitted.

5.3.1 Atlantic Puffins - Breeding Season, Individual Birds

Table 9: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 7					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.25	0.5	1	2
Expert 2	0.01	0.50	1.0	4	20
Expert 3	0.00	0.50	1.0	15	25
Expert 4	1.00	3.00	6.0	10	17
Expert 5	0.00	2.00	5.0	10	50
Expert 6	0.00	5.00	10.0	30	50
Expert 7	0.00	0.50	2.0	3	10

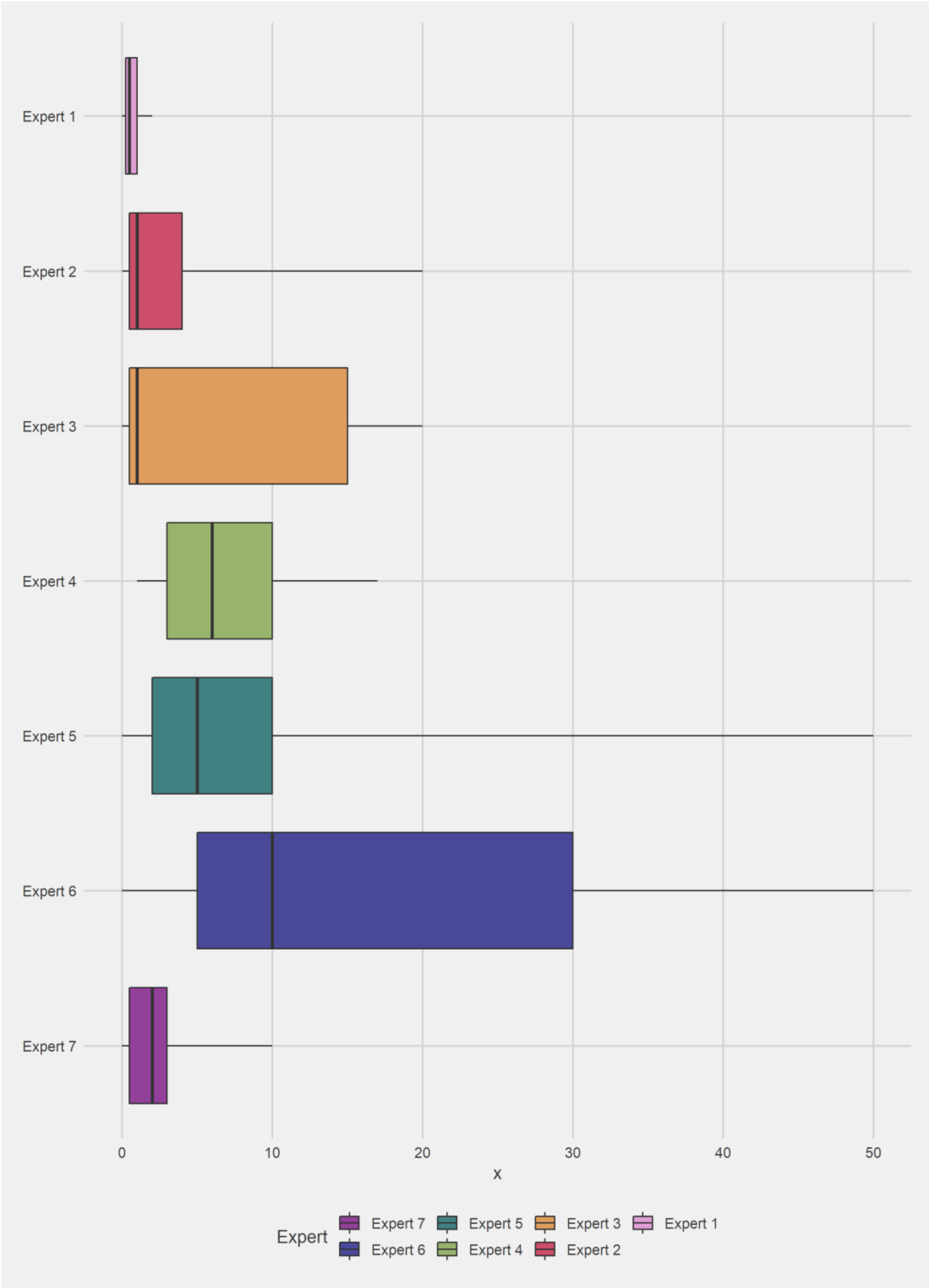

Figure 28: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

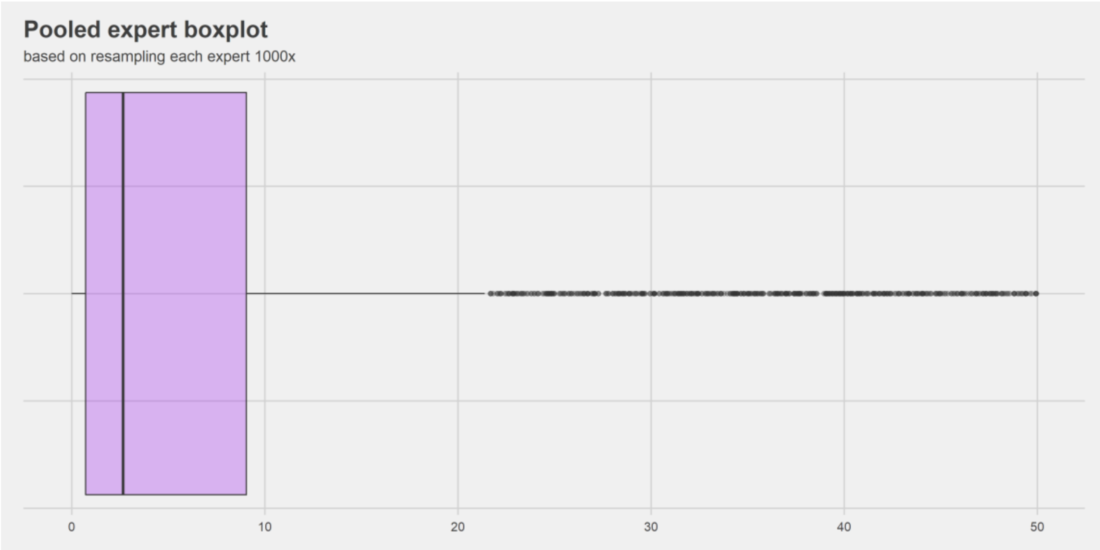

Figure 29: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

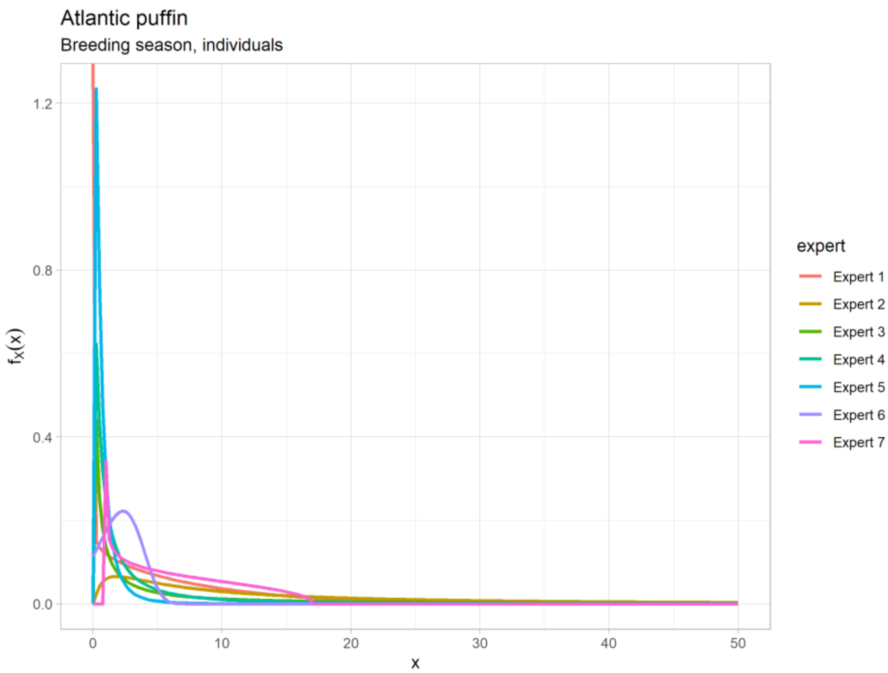

Figure 30: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

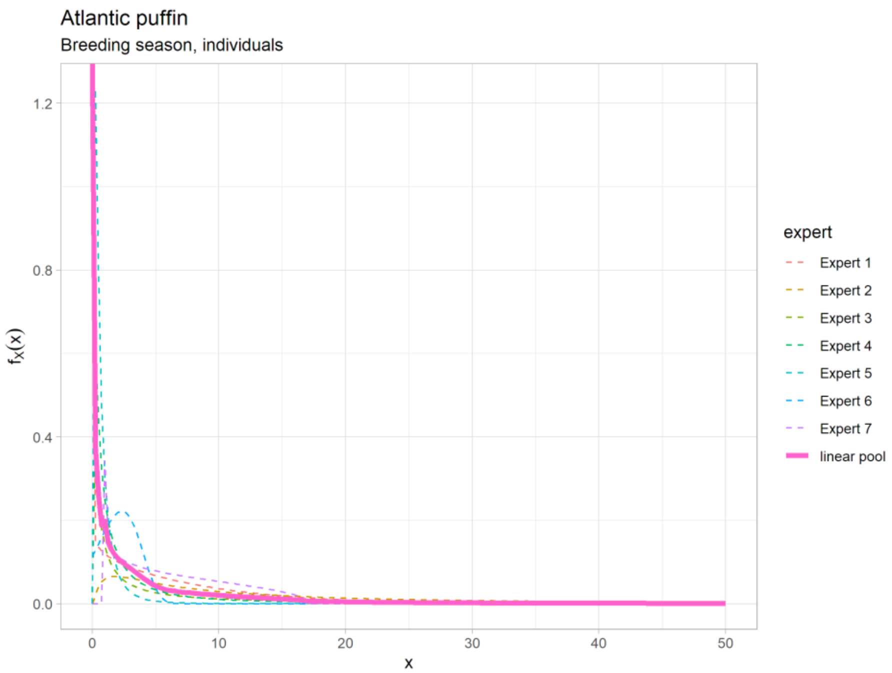

Figure 31: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.3.2 Guillemots - Breeding Season, Individual Birds

Table 10: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 1					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.20	0.5	1.0	2
Expert 2	0.01	0.50	1.0	4.0	20
Expert 3	0.00	1.00	2.0	15.0	25
Expert 4	1.00	4.00	5.0	15.0	50
Expert 5	0.00	2.00	5.0	10.0	50
Expert 6	0.00	5.00	10.0	30.0	50
Expert 7	0.00	0.25	1.0	1.5	4

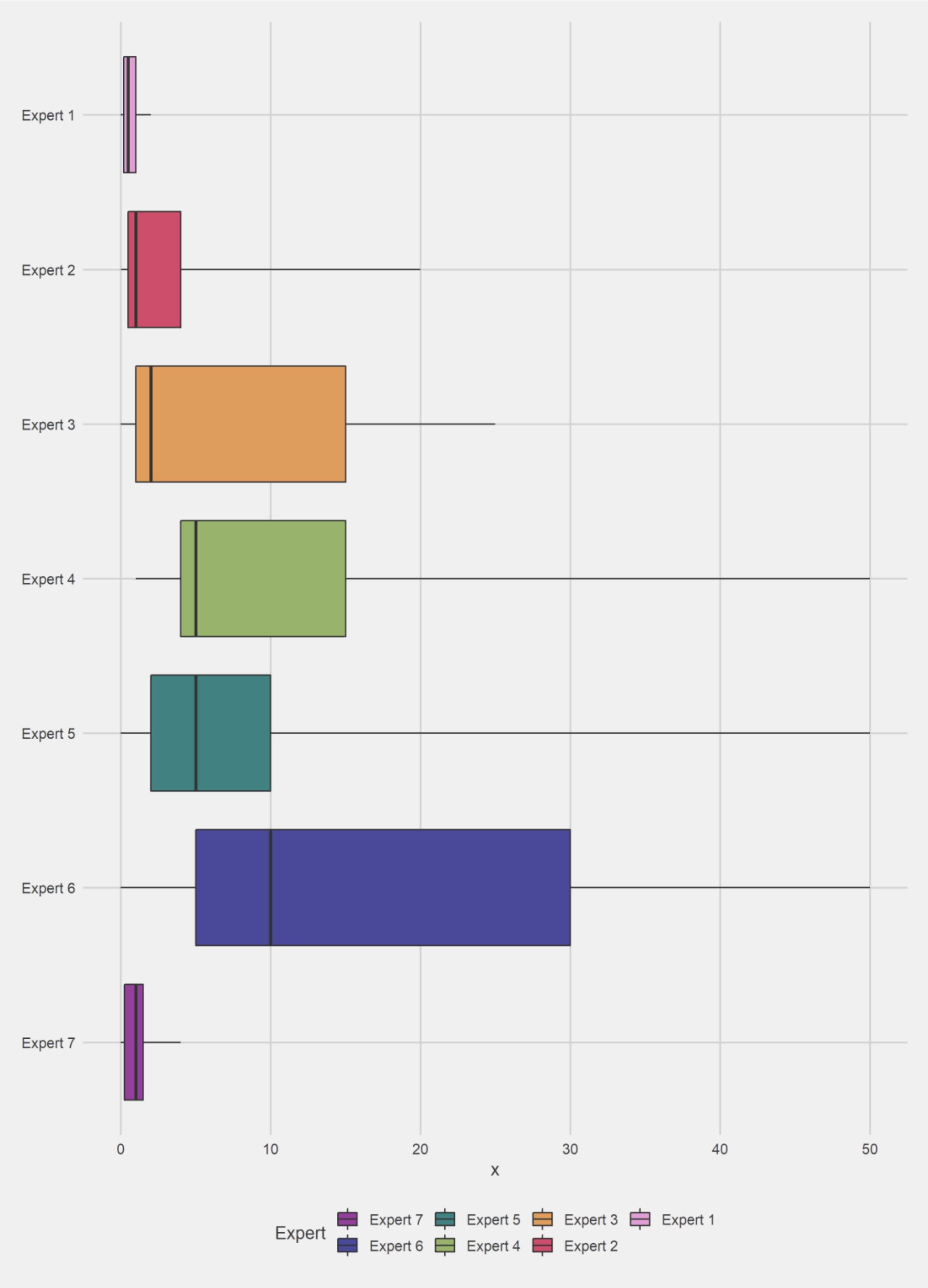

Figure 32: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

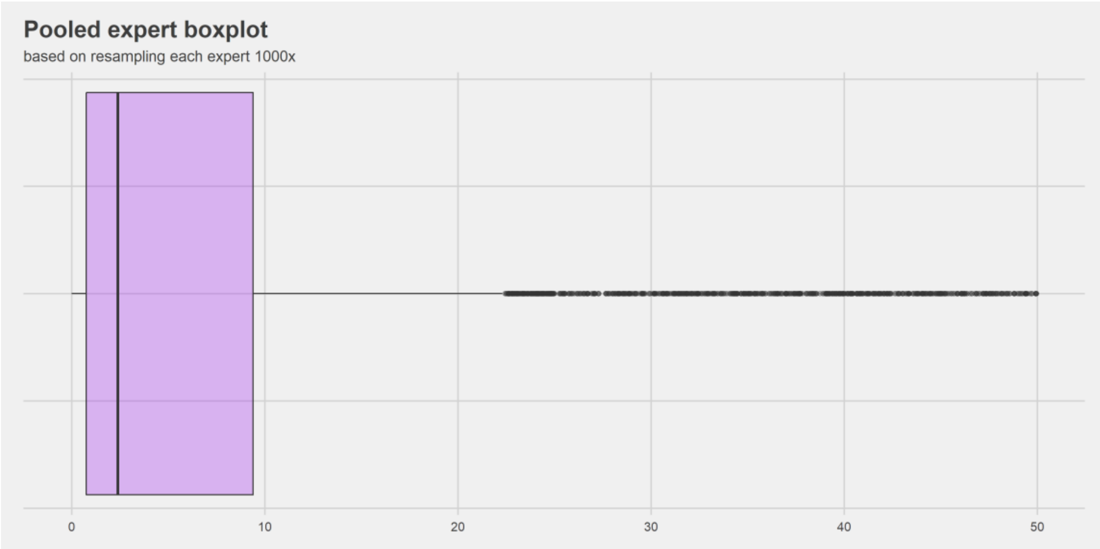

Figure 33: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

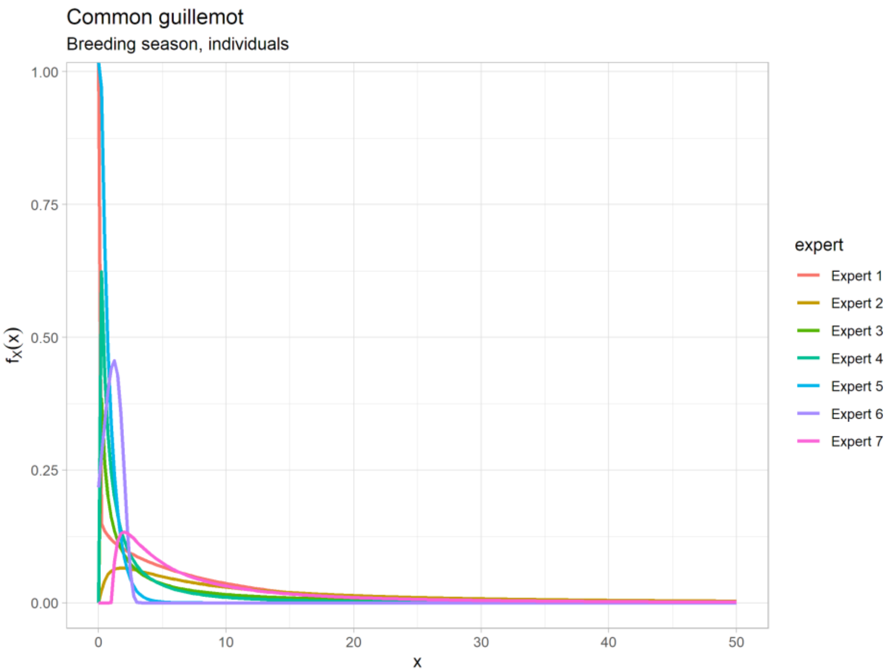

Figure 34: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

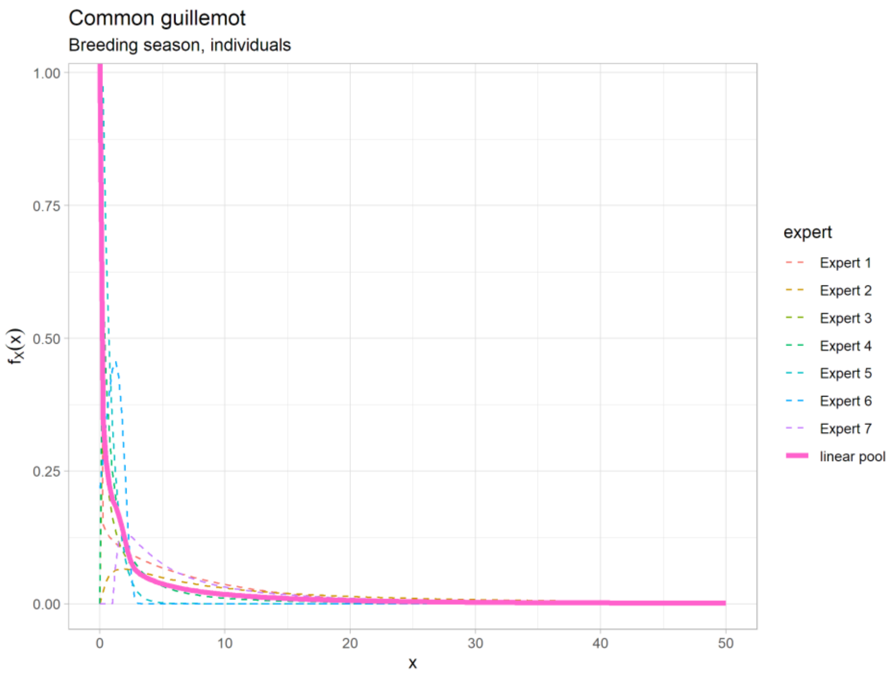

Figure 35: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.3.3 Black-legged kittiwakes - Breeding Season, Individual Birds

Table 11: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 10					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.2	0.3	0.5	1
Expert 2	0.01	1.0	2.0	8.0	40
Expert 3	0.00	1.0	2.0	15.0	25
Expert 4	1.00	3.0	5.0	10.0	30
Expert 5	0.00	5.0	10.0	15.0	60
Expert 6	0.00	5.0	10.0	30.0	50
Expert 7	0.00	1.0	3.0	4.0	10

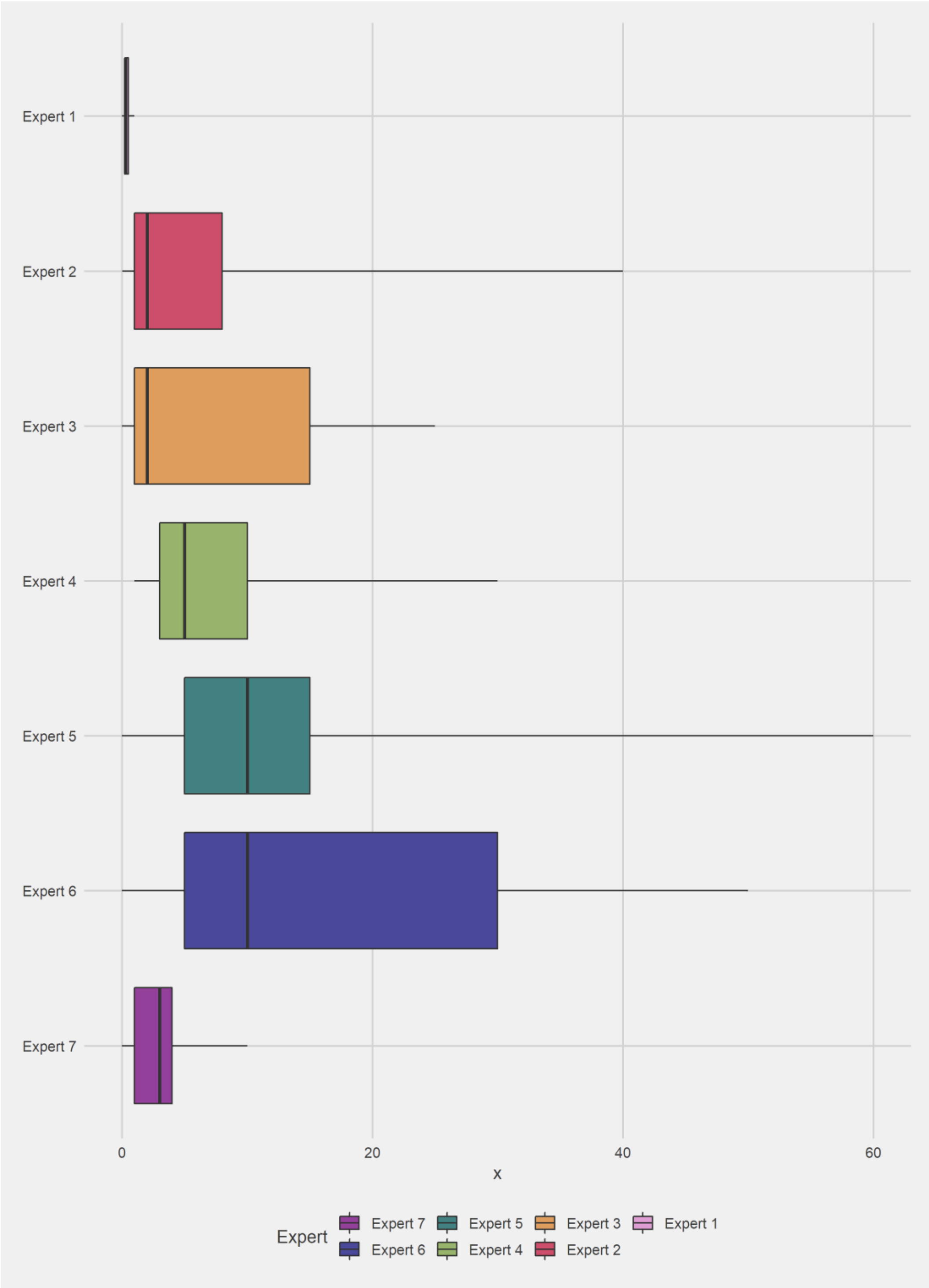

Figure 36: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

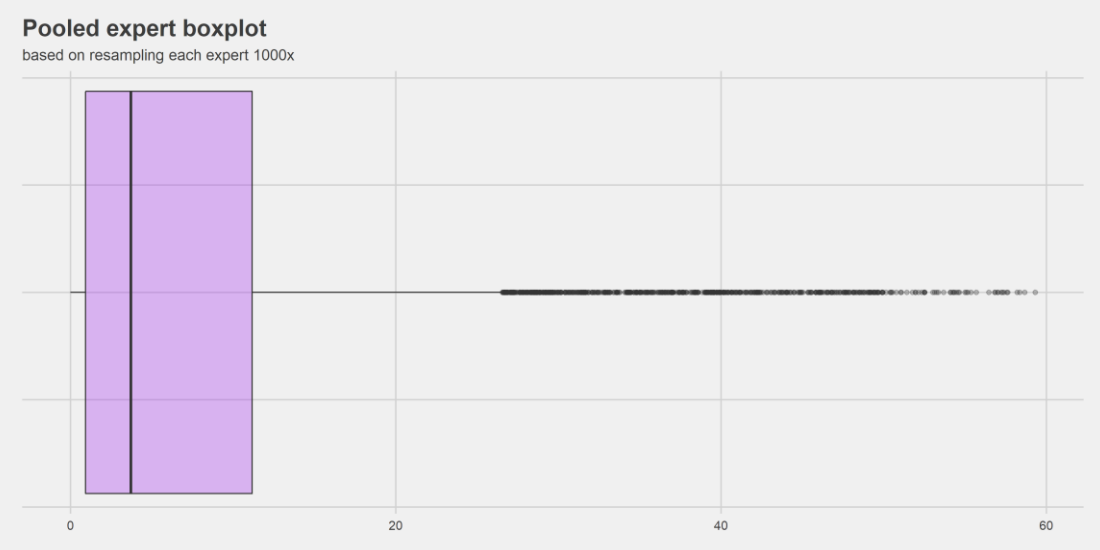

Figure 37: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

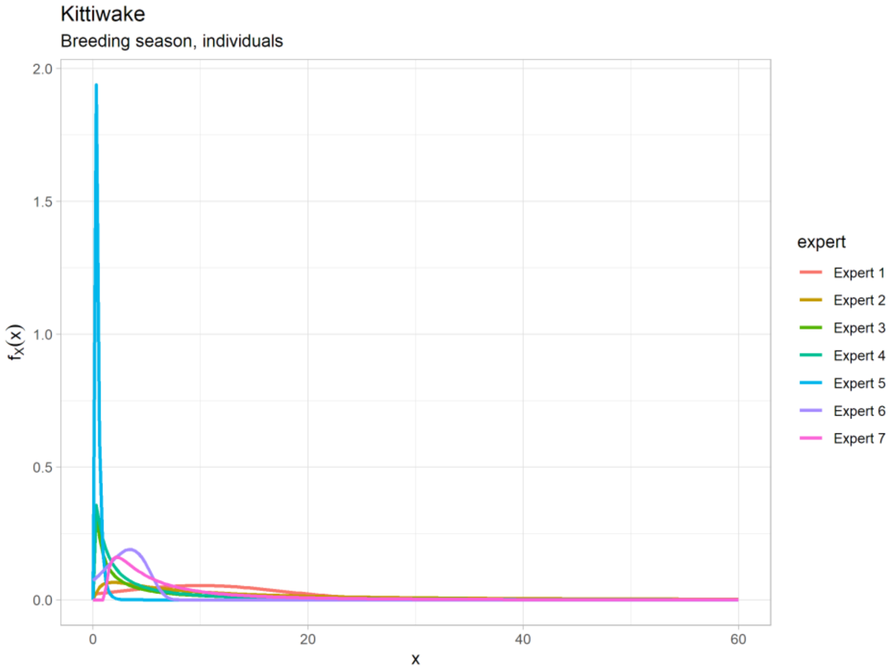

Figure 38: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

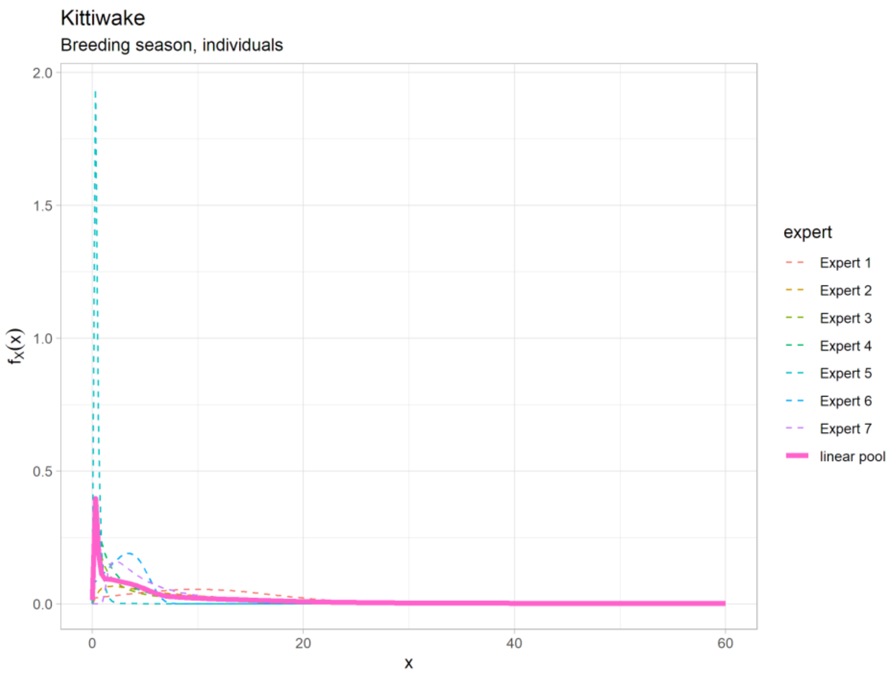

Figure 39: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.3.4 Northern gannets - Breeding Season, Individual Birds

Table 12: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 13					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.20	0.3	0.5	1
Expert 2	0.01	0.25	0.5	2.0	10
Expert 3	0.00	0.25	0.5	2.0	20
Expert 4	1.00	2.00	3.0	10.0	20
Expert 5	0.00	1.00	2.0	5.0	40
Expert 6	0.00	12.50	25.0	37.5	50
Expert 7	0.00	0.20	0.5	1.0	2

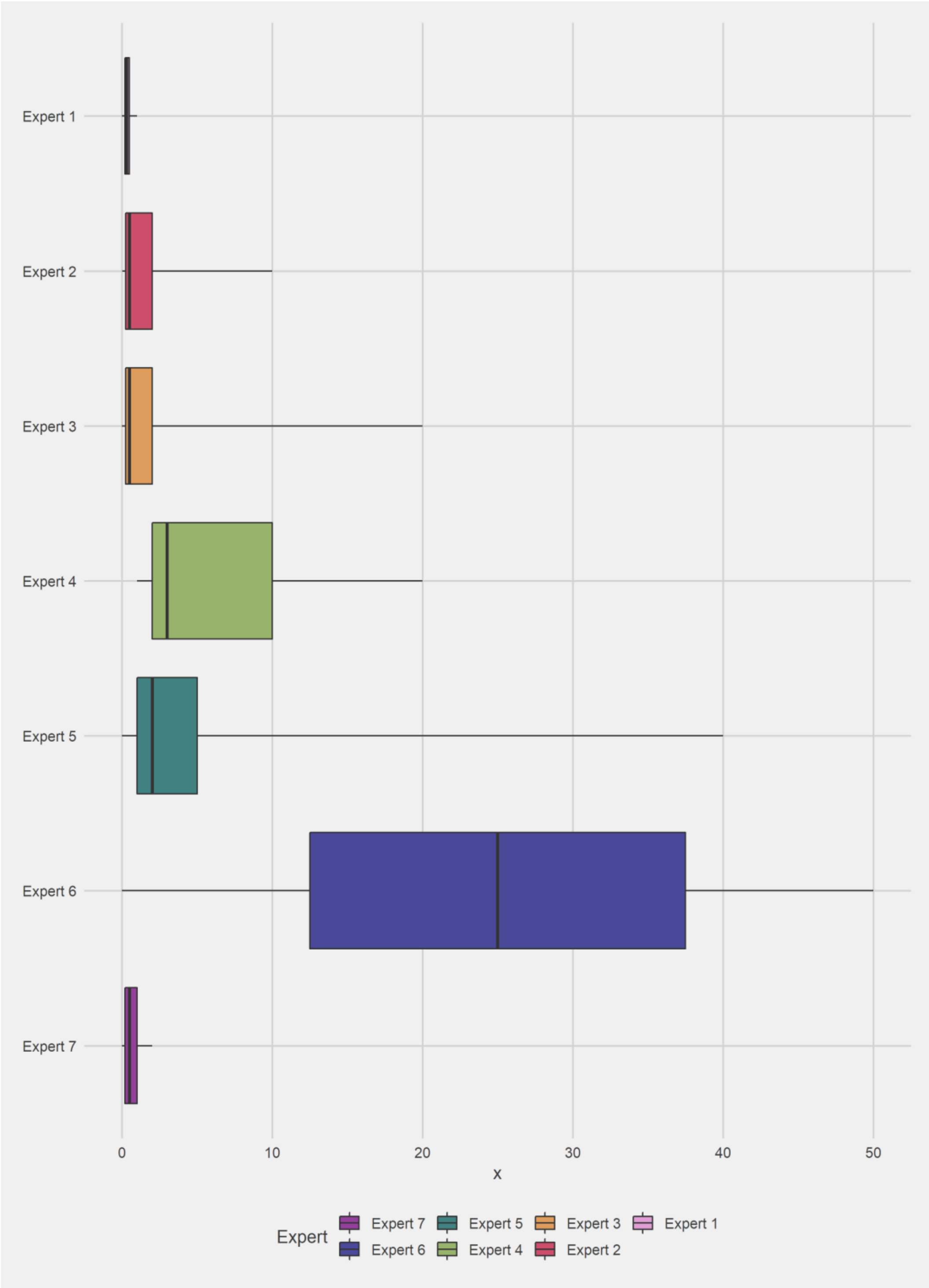

Figure 40: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

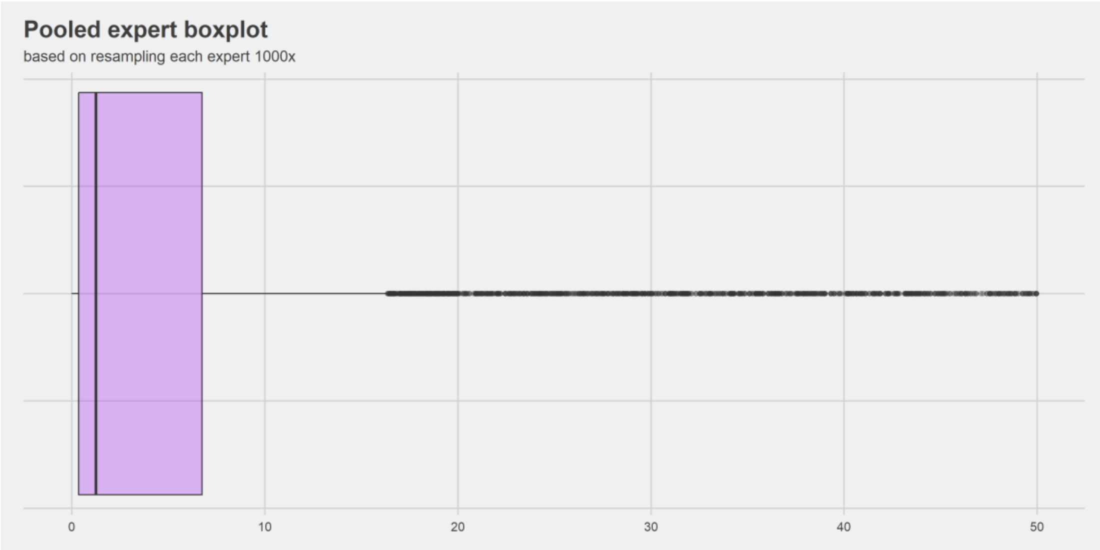

Figure 41: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

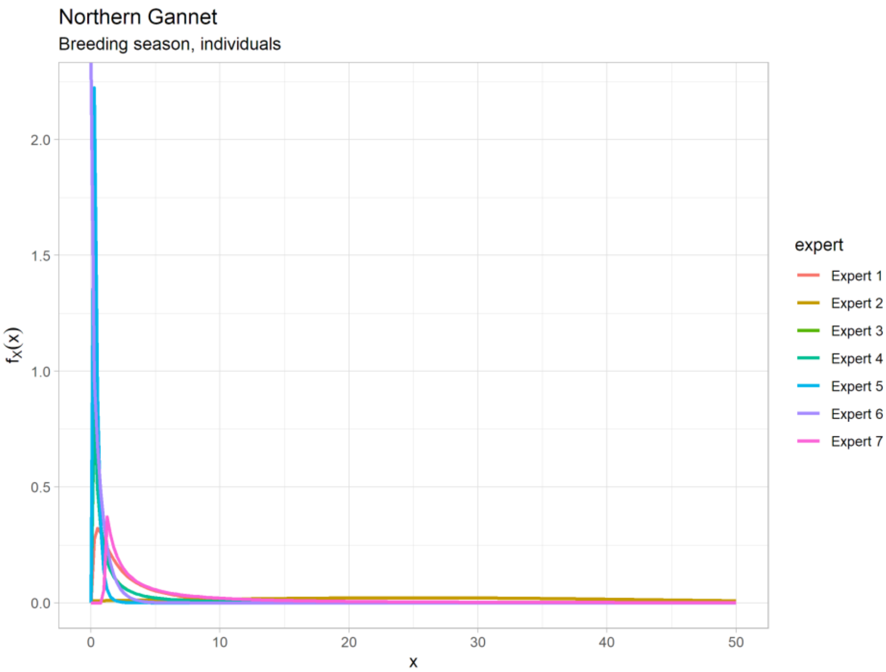

Figure 42: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

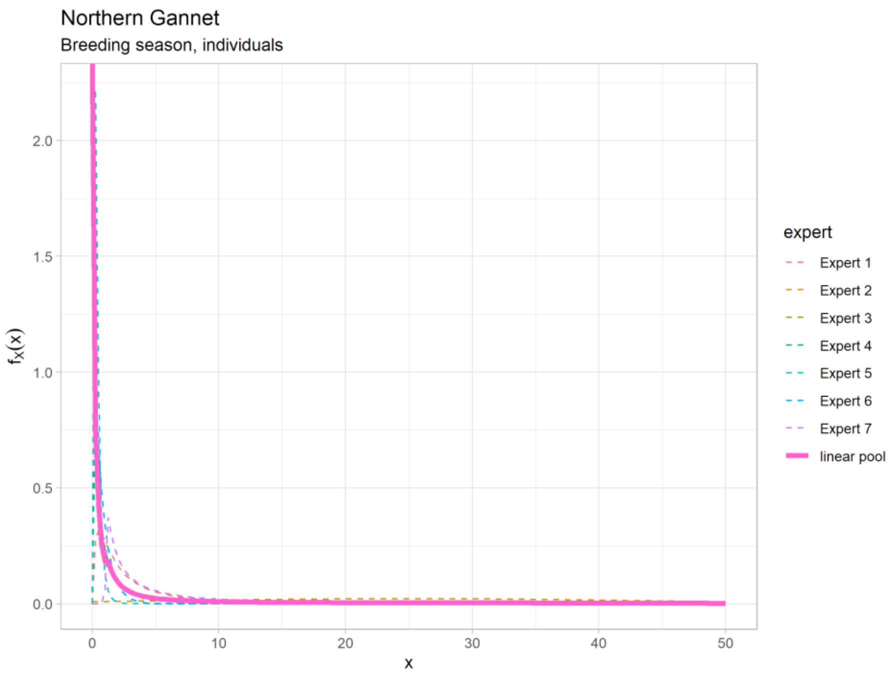

Figure 43: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.3.5 Razorbills - Breeding Season, Individual Birds

Table 13: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 4					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	0.25	0.5	1	2
Expert 2	0.01	0.50	1.0	4	20
Expert 3	0.00	0.50	1.0	15	25
Expert 4	1.00	2.00	4.0	12	40
Expert 5	0.00	2.00	5.0	10	50
Expert 6	0.00	5.00	10.0	30	50
Expert 7	0.00	0.50	1.0	2	5

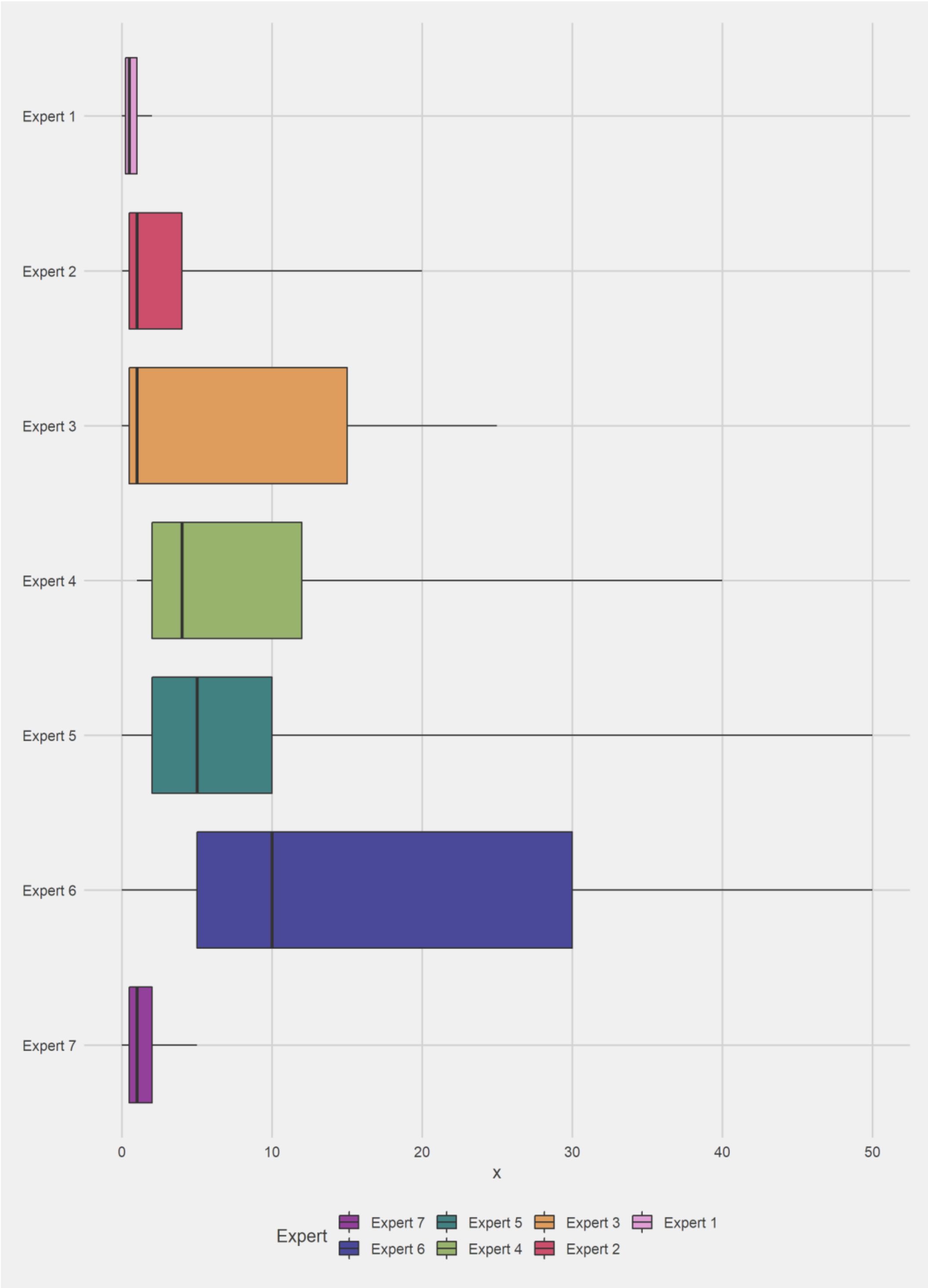

Figure 44: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

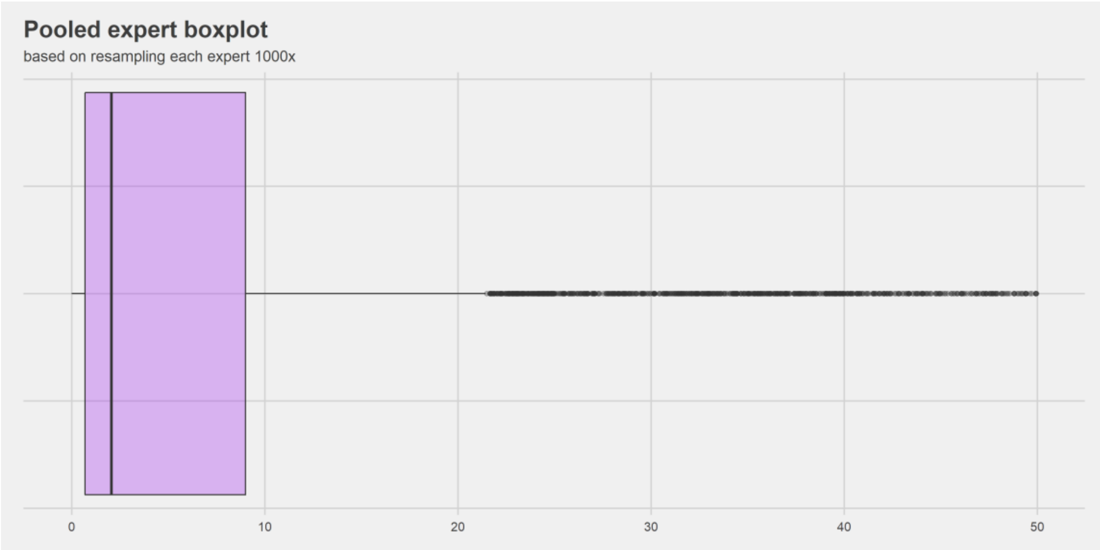

Figure 45: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

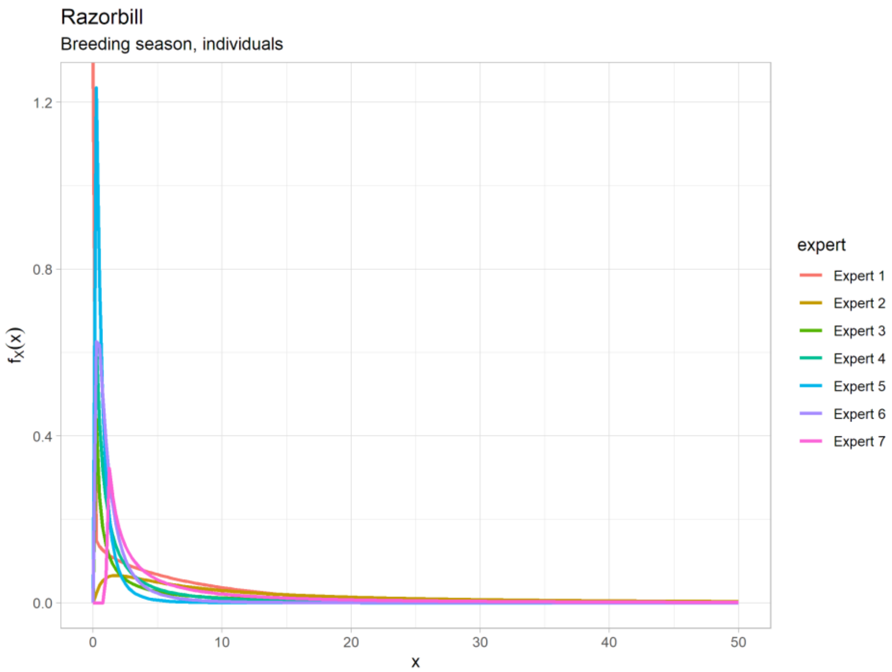

Figure 46: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

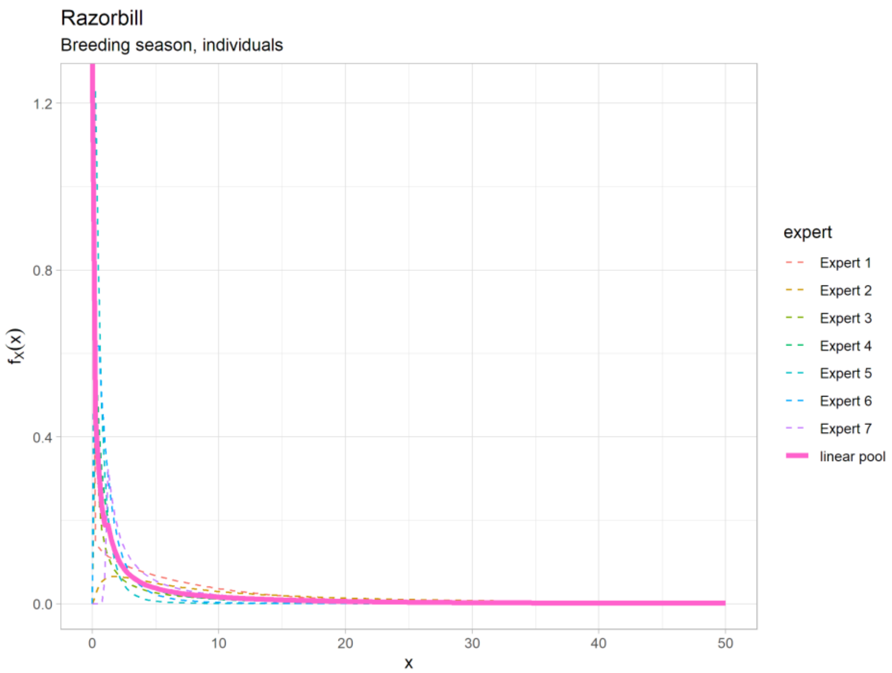

Figure 47: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

Table 14: Best fitting distribution and parameters for each expert for each of the questions. "Best" in this context are by objective selection via the SHELF methodology and tools (Oakley, 2021).

		Breeding season, individuals		
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Atlantic puffins	Expert A	beta	0.888	5.583
	Expert B	lognormal	2.417	1.35
	Expert C	lognormal	0.602	2.822
	Expert D	lognormal	0.188	1.609
	Expert E	lognormal	-0.693	1.028
	Expert F	mirrorlognormal	2.09	0.227
	Expert G	beta	0.888	5.583
	Expert A	beta	0.888	5.583

Breeding season, individuals				
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Common guillemot	Expert B	lognormal	2.417	1.35
	Expert C	lognormal	1.081	2.166
	Expert D	lognormal	0.188	1.609
	Expert E	gamma	0.968	1.335
	Expert F	mirrorlognormal	1.11	0.301
	Expert G	lognormal	1.677	1.295
Kittiwake	Expert A	normal	10	7.413
	Expert B	lognormal	2.417	1.35
	Expert C	lognormal	1.081	2.166
	Expert D	lognormal	0.886	1.603
	Expert E	lognormal	-1.174	0.682
	Expert F	mirrorlognormal	1.973	0.306
	Expert G	lognormal	1.419	1.117
Northern Gannet	Expert A	lognormal	0.756	1.2
	Expert B	normal	25	18.533
	Expert C	lognormal	-0.495	1.597
	Expert D	lognormal	-0.517	1.621
	Expert E	lognormal	-1.174	0.682
	Expert F	gamma	0.968	1.335
	Expert G	lognormal	0.927	1.7
Razorbill	Expert A	beta	0.888	5.583
	Expert B	lognormal	2.417	1.35
	Expert C	lognormal	0.602	2.822
	Expert D	lognormal	0.188	1.609

Breeding season, individuals				
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
	Expert E	lognormal	-0.693	1.028
	Expert F	lognormal	0	1.028
	Expert G	lognormal	1.155	1.782

5.4 Displacement mortality for dependents in the breeding season

The experts were asked to provide a set of values that would answer the following question:

> *The excess mortality rates (as an absolute %) for dependent birds that would have used the area of influence of the OWF and associated infrastructure if there had been no OWF, but which is displaced away from the area during construction and/or operation.*

Note, here 100% is interpreted as a complete nest-level failure e.g. nest abandonment, so is not dependent on a speculative number of chicks within the nest.

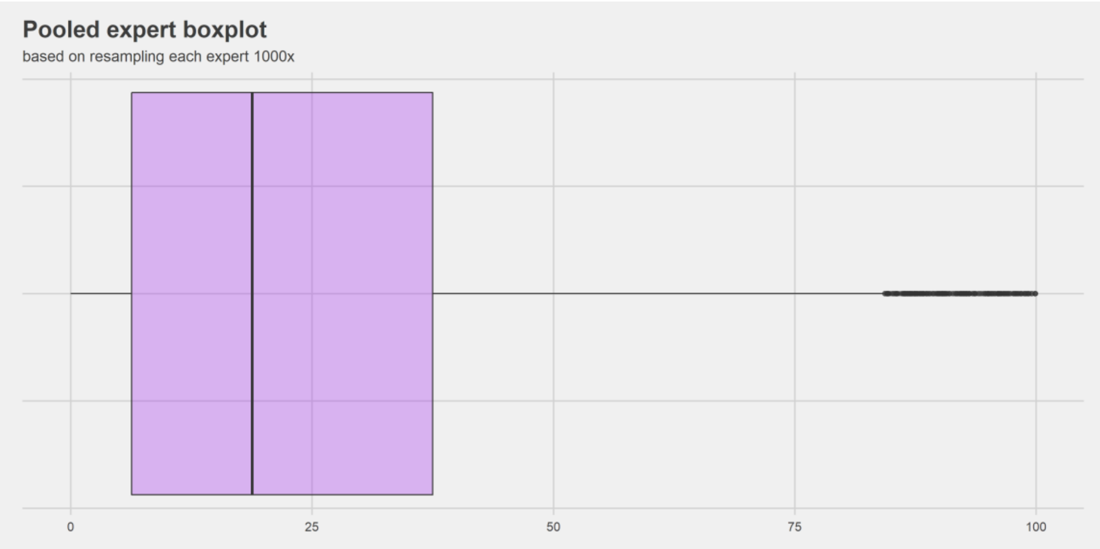

Figure 65: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

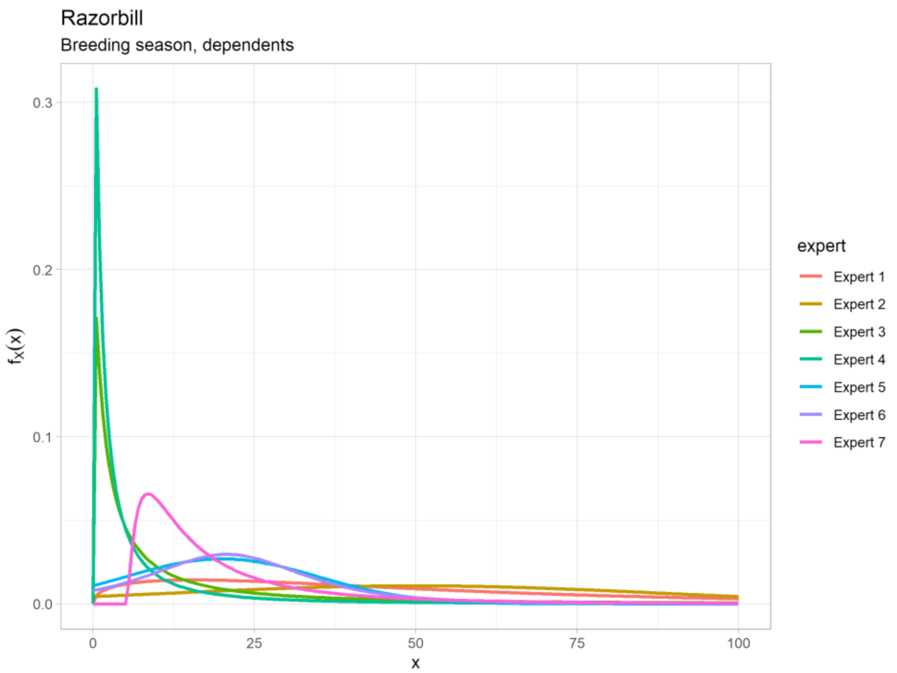

Figure 66 show the statistical distributions chosen by each of the experts, which are summarized here by fitted density functions, using the tools and selection criteria with the SHELF R package (Oakley, 2021). Detailed expert-level outputs are presented, including the raw values from which alternative functions might be fitted.

5.4.1 Atlantic Puffins - Breeding Season, Dependent Birds

Table 15: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 8					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	20	30	40	70
Expert 2	0.01	1	2	8	40
Expert 3	0.00	2	5	30	50
Expert 4	5.00	15	22	38	75
Expert 5	0.00	20	40	70	100
Expert 6	0.00	25	50	75	100
Expert 7	0.00	16	31	46	62

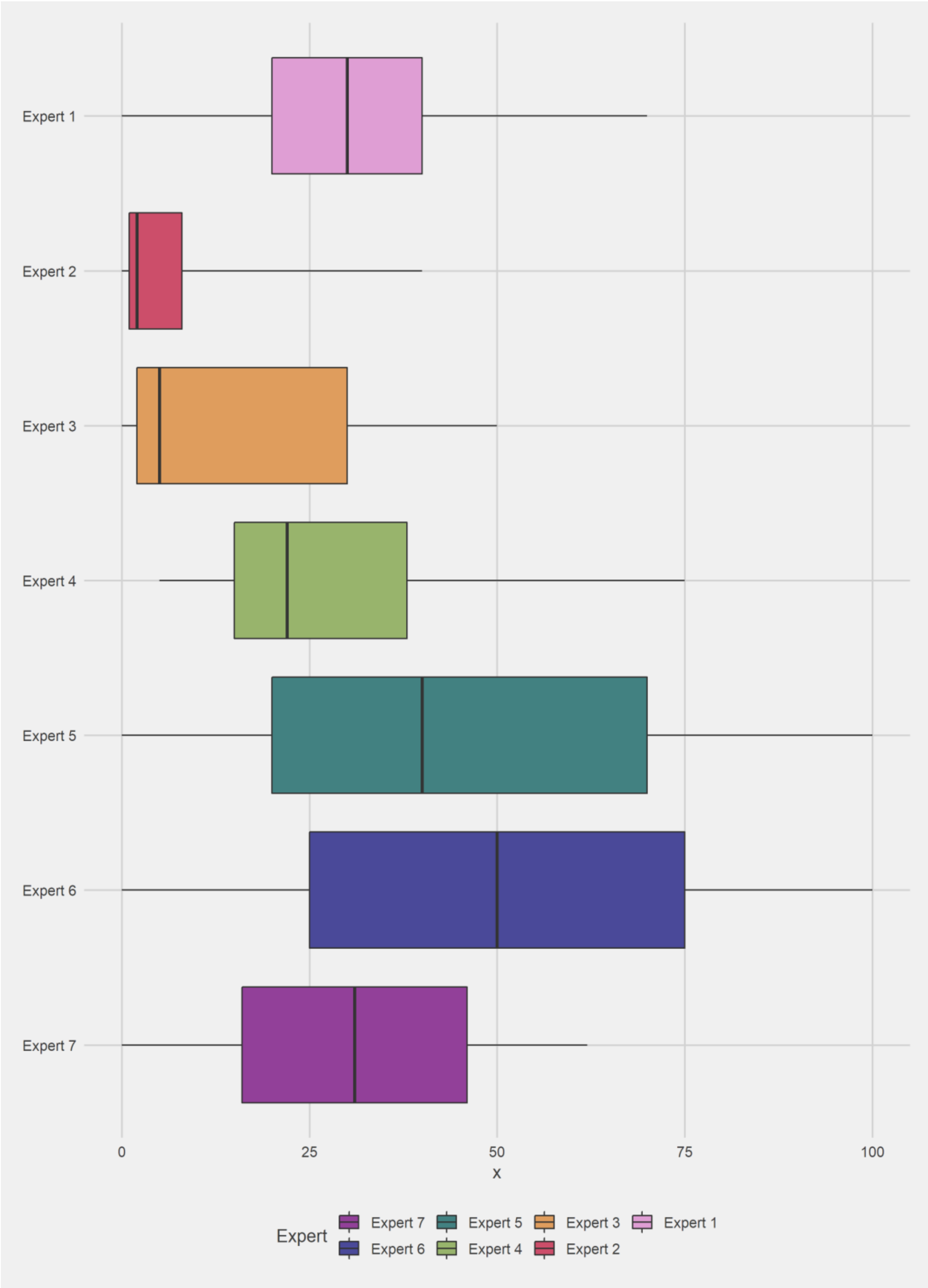

Figure 48: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

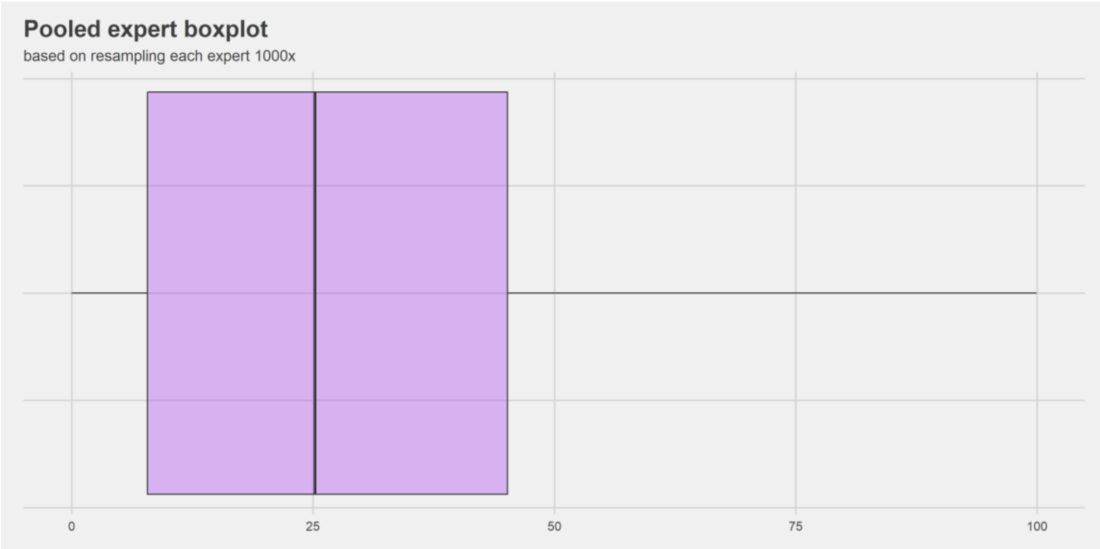

Figure 49: A boxplot representing the accumulated experts. Created from simple resampling of expert’s distributions.

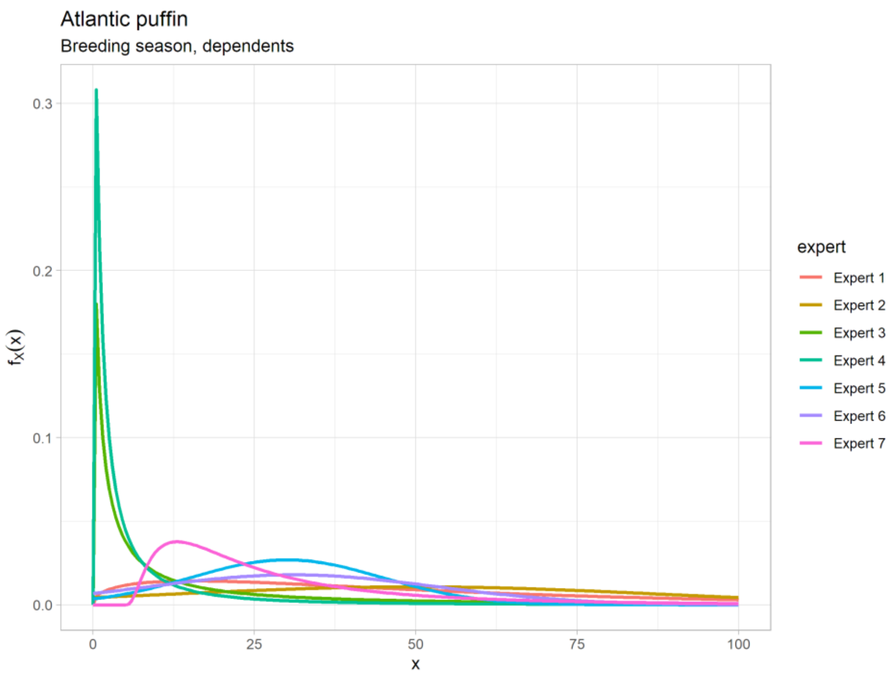

Figure 50: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

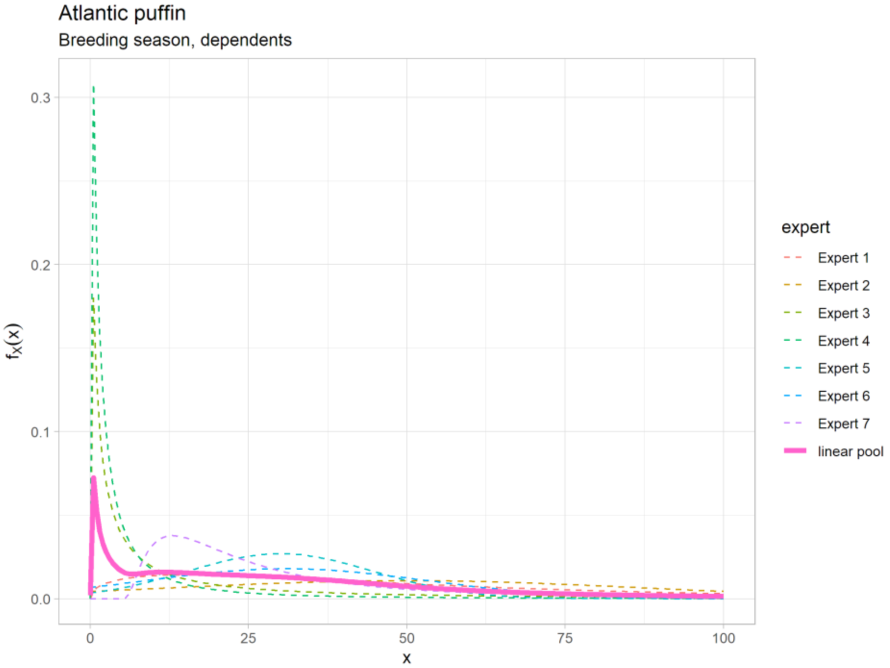

Figure 51: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.4.2 Guillemots - Breeding Season, Dependent Birds

Table 16: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 2

Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	20.0	30	40	70
Expert 2	0.01	1.0	2	8	40
Expert 3	1.00	7.5	15	25	50
Expert 4	5.00	12.0	20	30	70
Expert 5	0.00	20.0	40	70	100
Expert 6	0.00	25.0	50	75	100
Expert 7	0.00	9.0	17	25	34

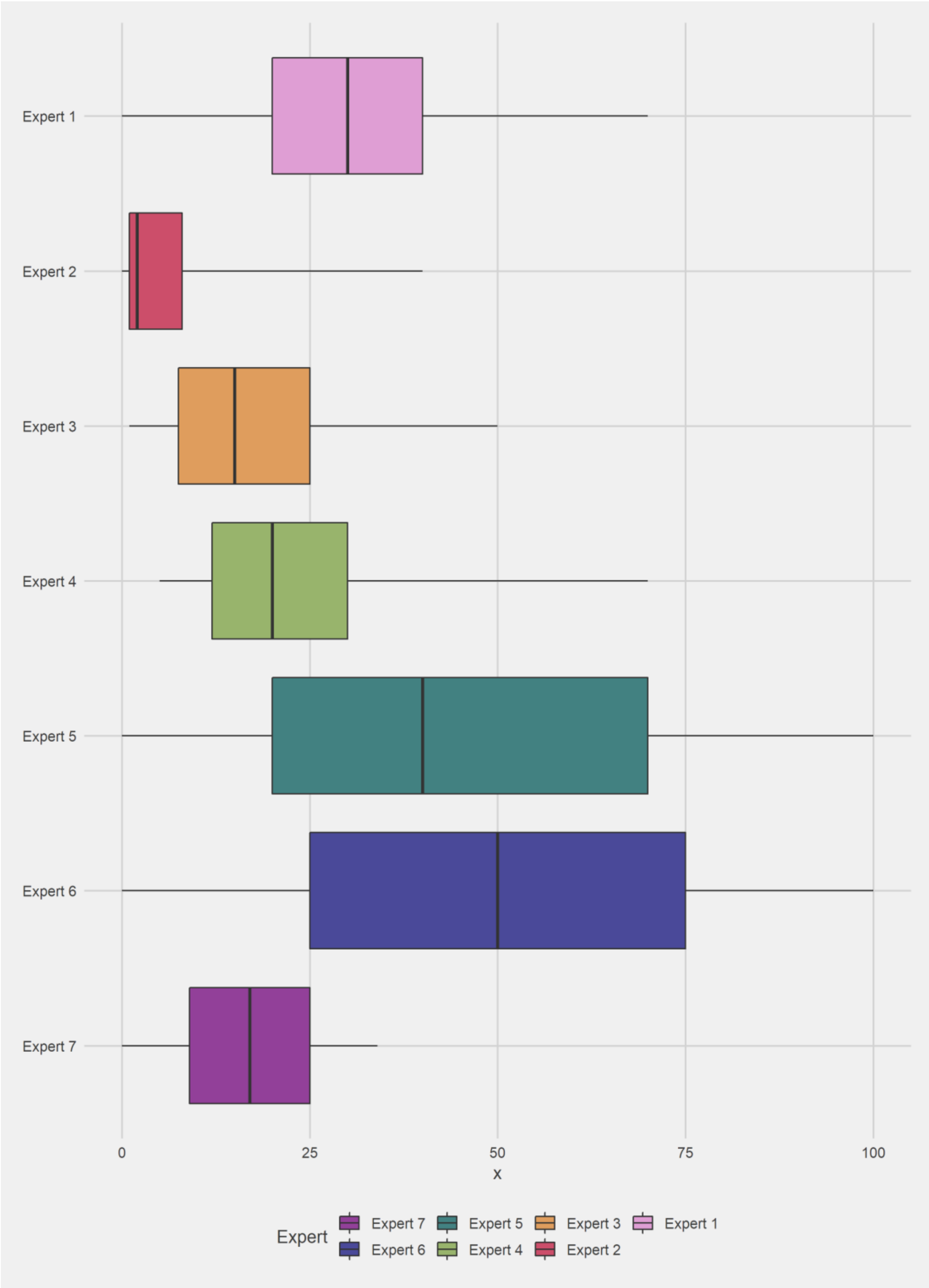

Figure 52: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

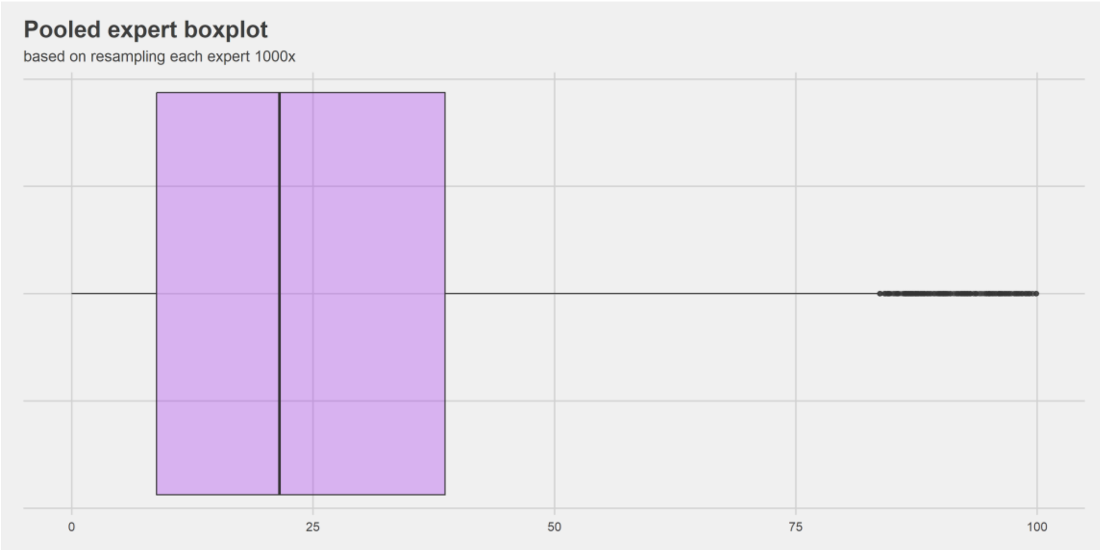

Figure 53: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

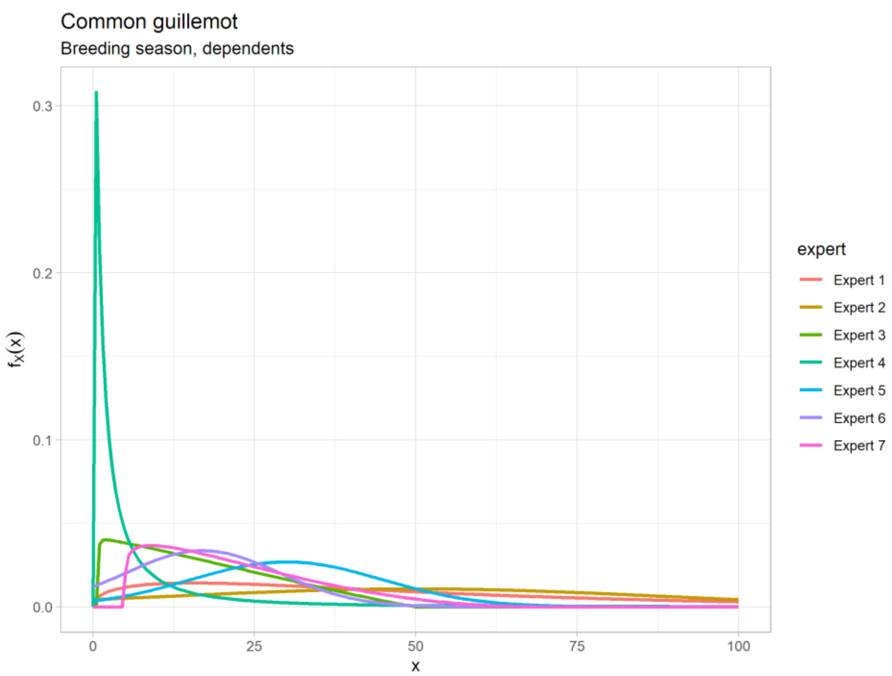

Figure 54: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

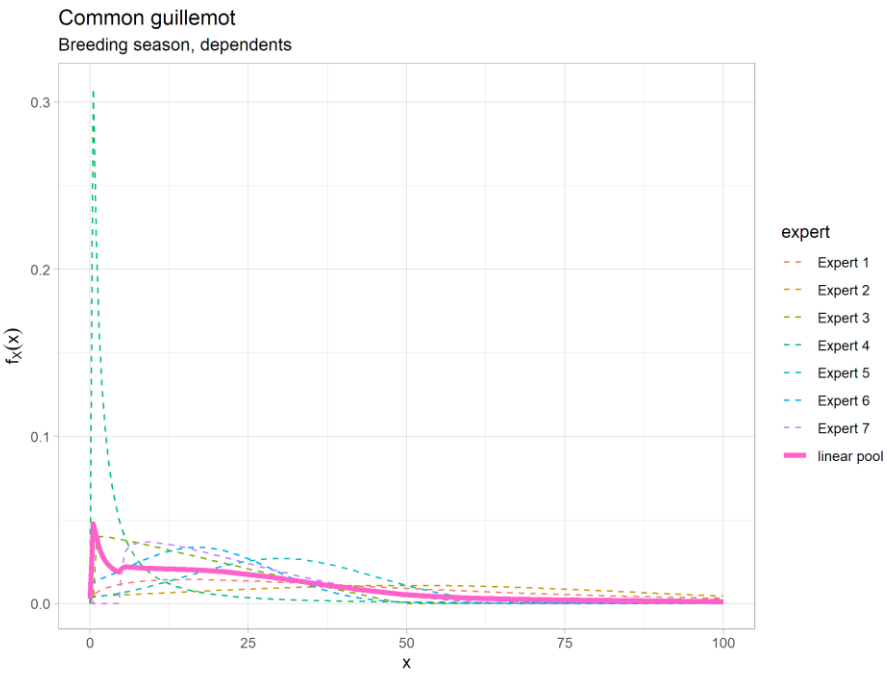

Figure 55: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.4.3 Black-legged kittiwakes - Breeding Season, Dependent Birds

Table 17: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 11					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	5.0	10	15	30
Expert 2	0.01	2.0	4	16	80
Expert 3	0.00	7.5	15	30	50
Expert 4	5.00	17.0	27	40	70
Expert 5	0.00	20.0	50	80	100
Expert 6	0.00	25.0	50	75	100
Expert 7	0.00	9.0	17	25	35

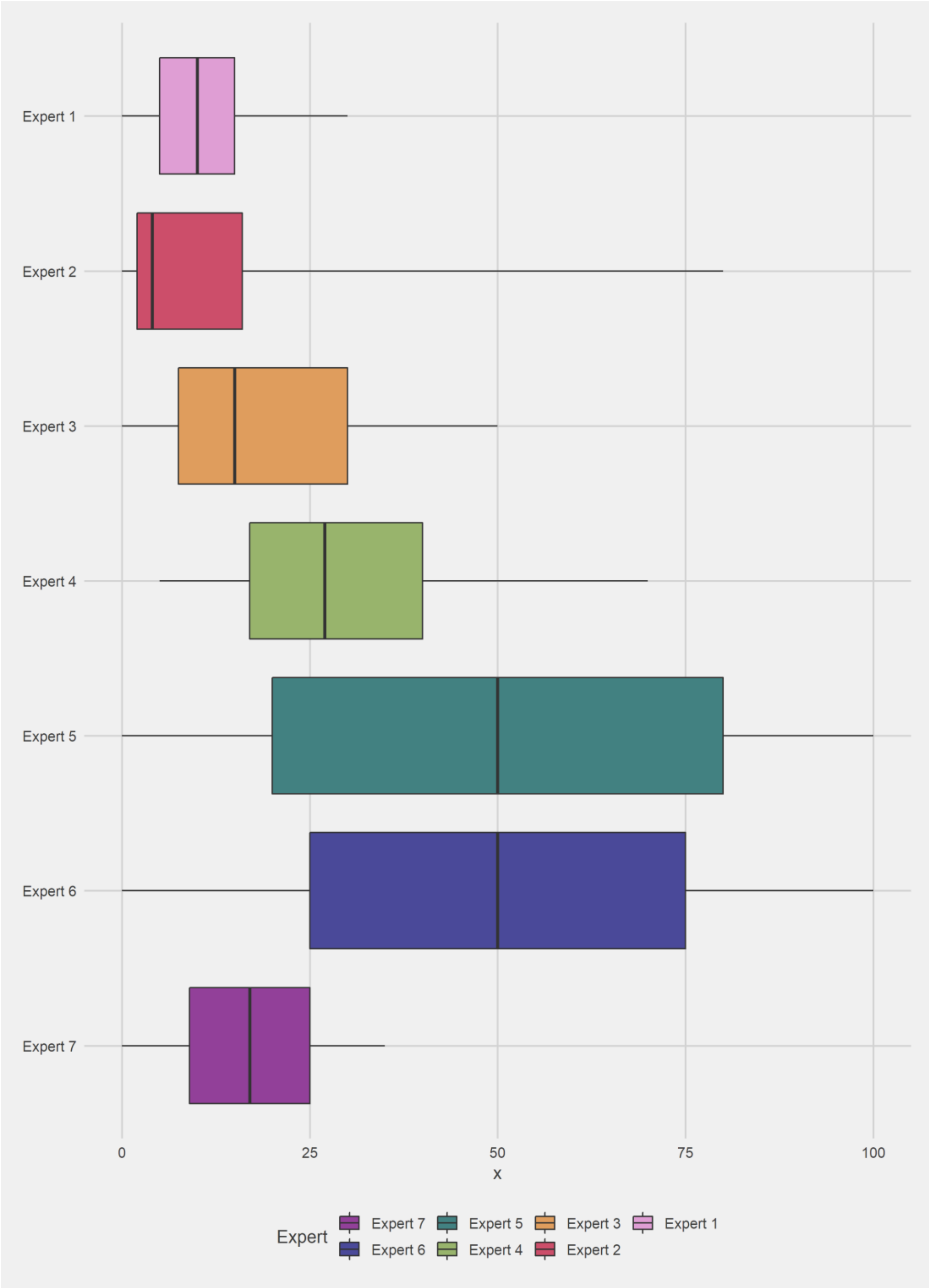

Figure 56: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

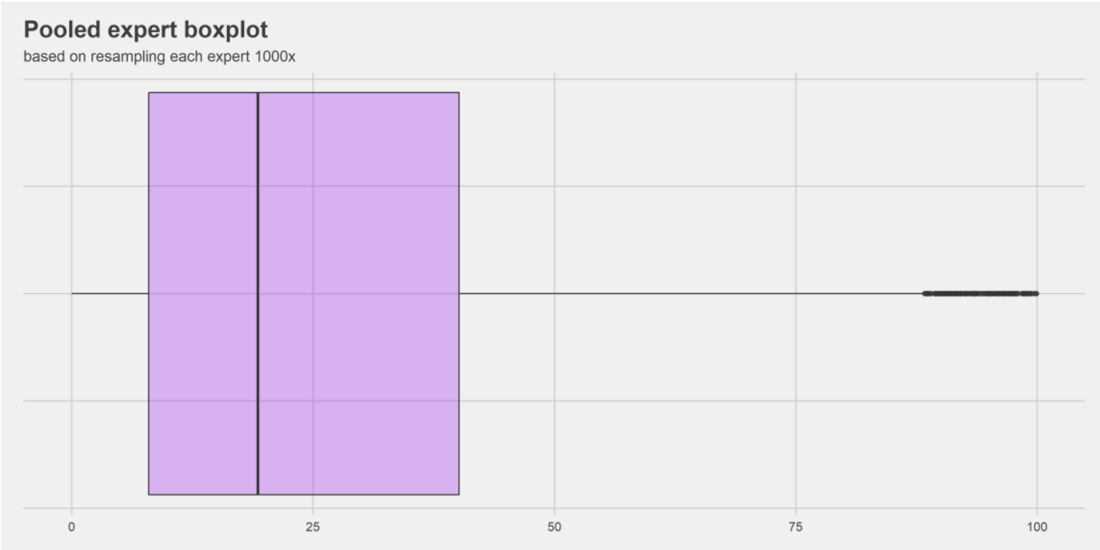

Figure 57: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

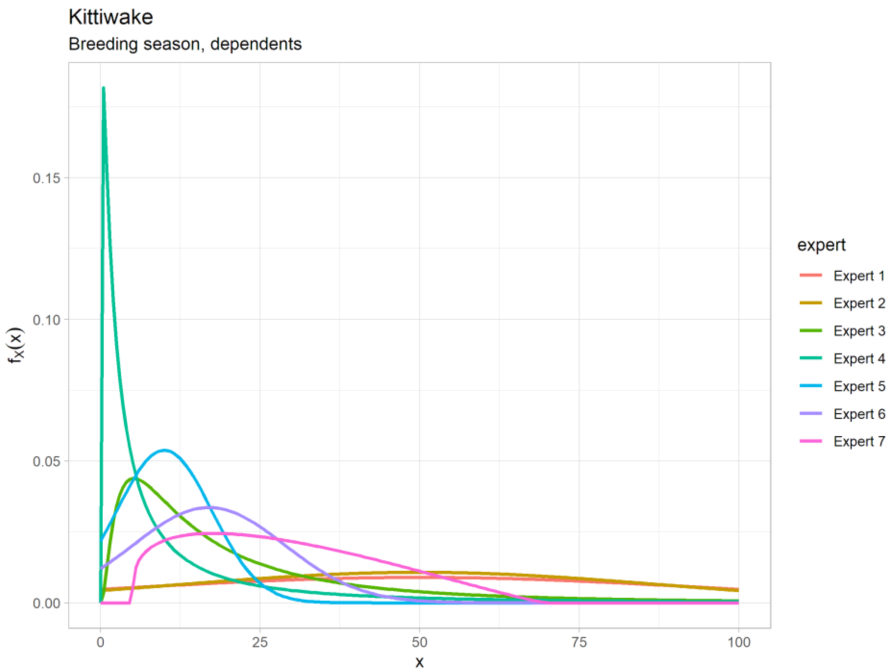

Figure 58: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

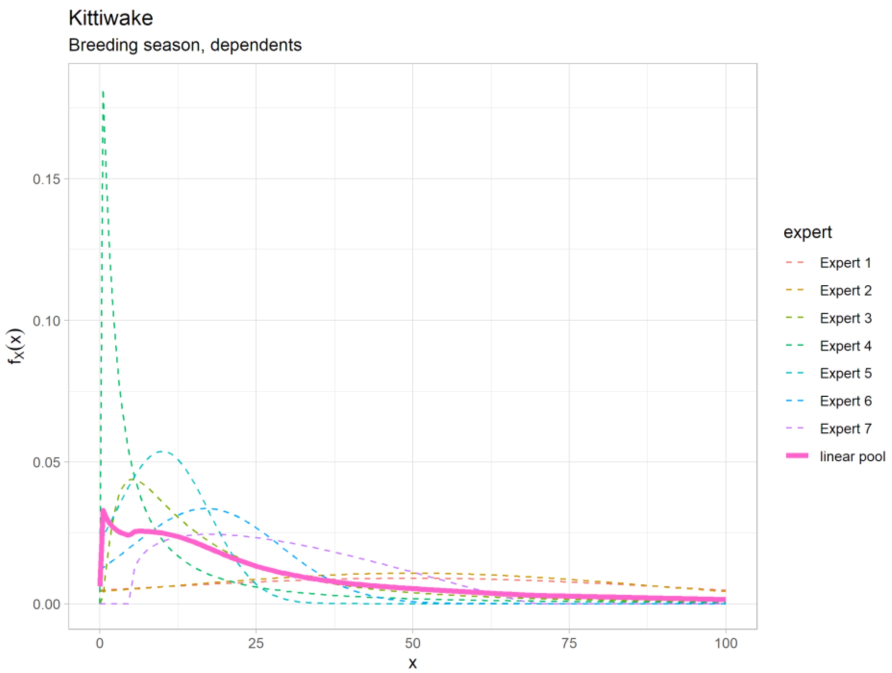

Figure 59: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.4.4 Northern gannets - Breeding Season, Dependent Birds

Table 18: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 14					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	5.0	10	15	40
Expert 2	0.01	0.5	1	4	20
Expert 3	1.00	7.5	15	25	50
Expert 4	3.00	7.0	12	19	50
Expert 5	0.00	15.0	30	45	100
Expert 6	0.00	25.0	50	75	100
Expert 7	0.00	5.0	9	13	18

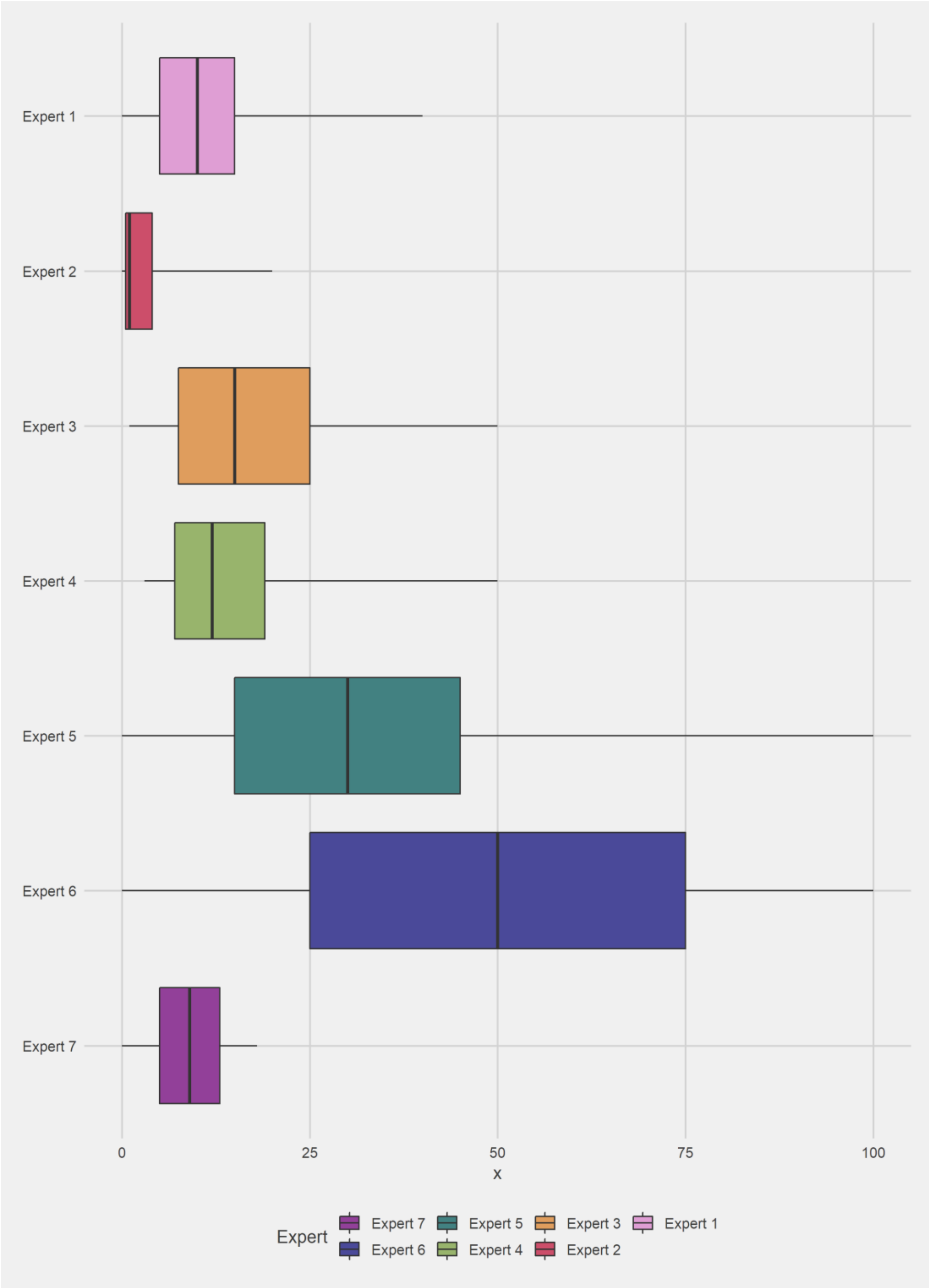

Figure 60: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

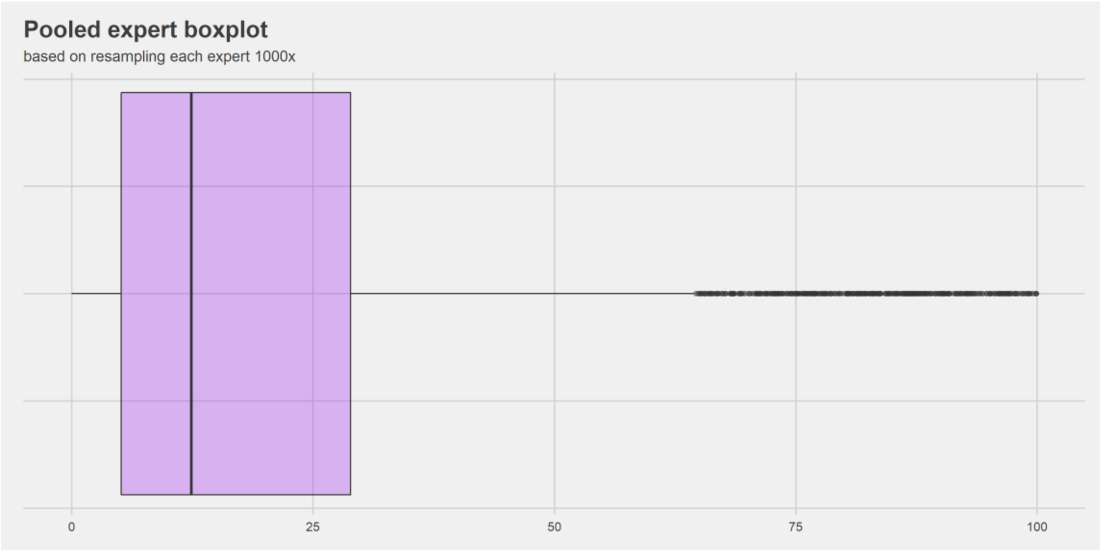

Figure 61: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

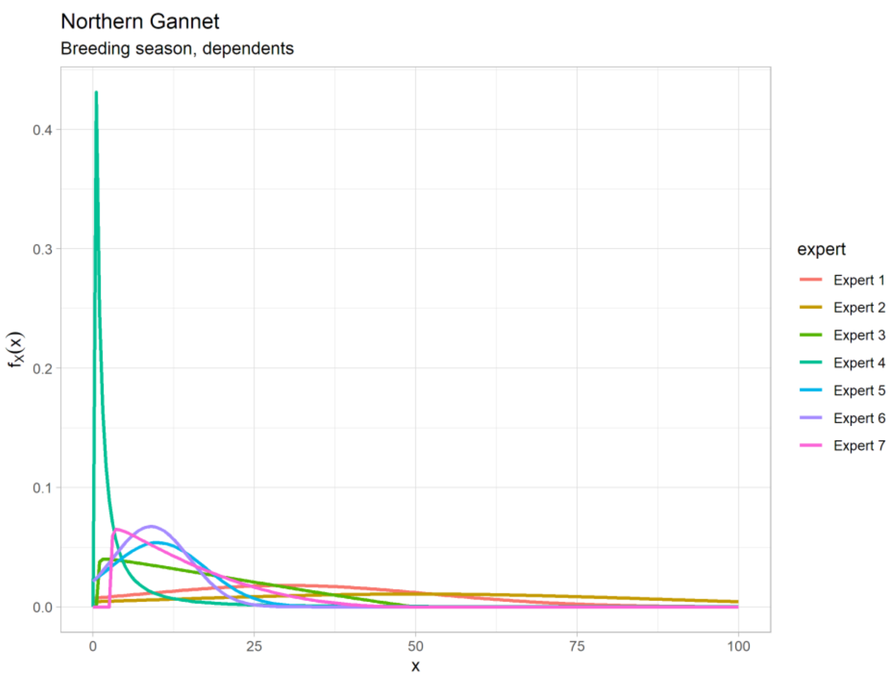

Figure 62: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

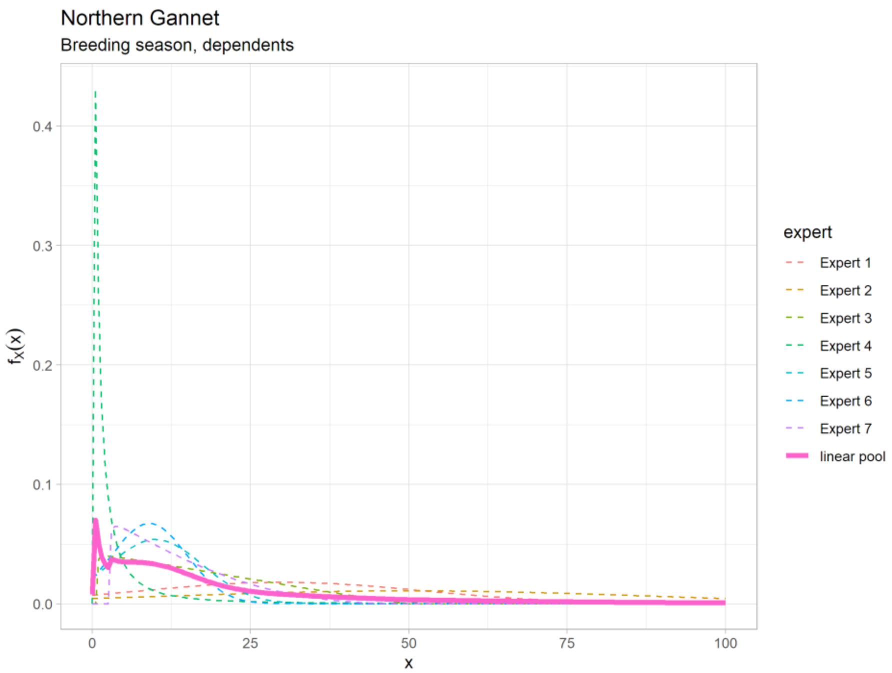

Figure 63: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

5.4.5 Razorbills - Breeding Season, Dependent Birds

Table 19: Experts' values for the five reference points used to define the distribution of the value of interest (absolute %-age excess mortality)

Question 5					
Expert	Lower	Lower Quartile	Median	Upper Quartile	Upper
Expert 1	0.00	10	20	30	60
Expert 2	0.01	1	2	8	40
Expert 3	0.00	2	5	20	50
Expert 4	5.00	10	15	25	60
Expert 5	0.00	20	40	70	100
Expert 6	0.00	25	50	75	100
Expert 7	0.00	11	21	30	42

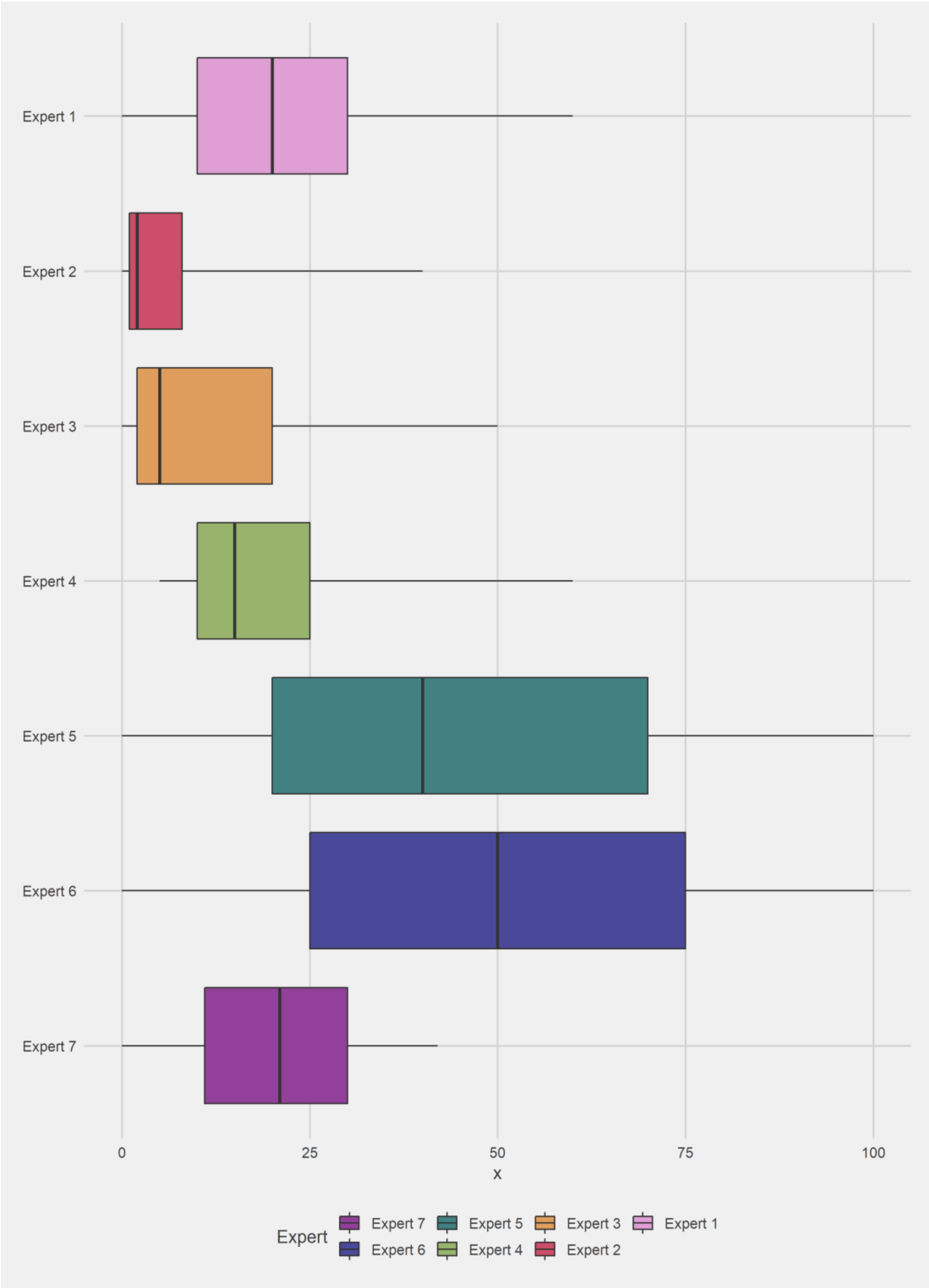

Figure 64: Elicited parameter values (X %-age excess mortality) represented in box-style plots, presenting minimum, maximum (end of whiskers), and the 25th, 50th, and 75th percentiles (left edge of the box, dark line inside the box, and right edge of the box).

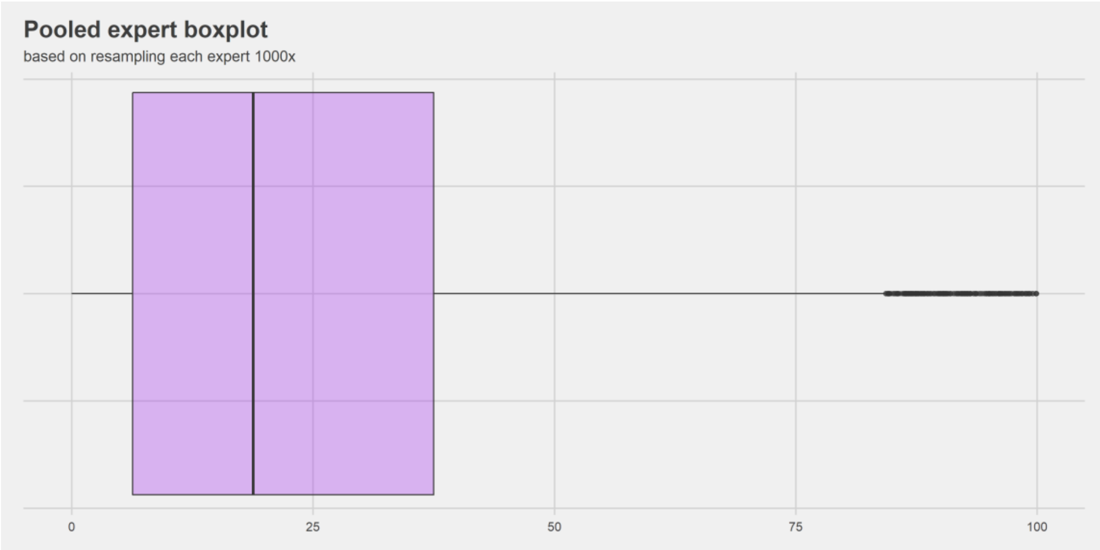

Figure 65: A boxplot representing the accumulated experts. Created from simple resampling of expert's distributions.

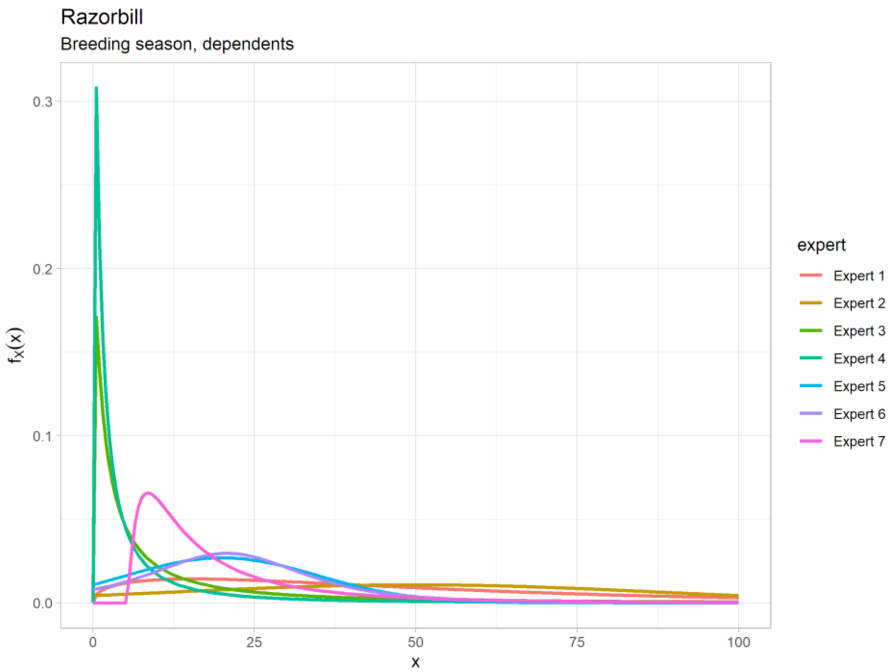

Figure 66: Fitted statistical distributions for each expert's responses. Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

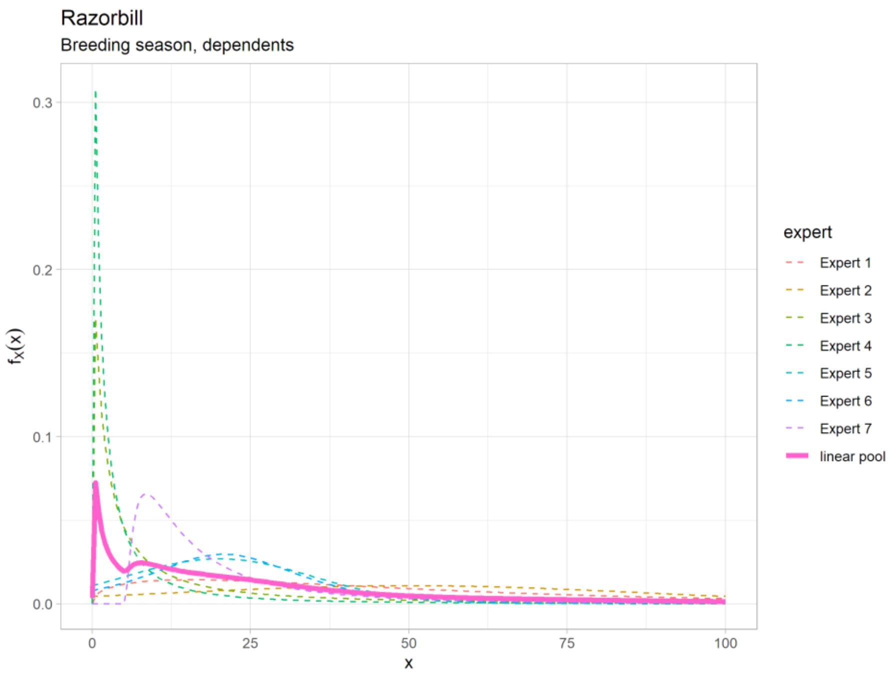

Figure 67: Curve of linearly pooled experts (bold), with fitted statistical distributions for each expert's responses (dashed). Fitted curves forms are automatically selected using criteria within the SHELF R package (Oakley, 2021).

Table 20: Best fitting distribution and parameters for each expert for each of the questions. "Best" in this context are by objective selection via the SHELF methodology and tools (Oakley, 2021).

		Breeding season, dependents		
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Atlantic puffins	Expert A	gamma	1.438	0.028
	Expert B	normal	50	37.065
	Expert C	lognormal	1.86	2.075
	Expert D	lognormal	0.886	1.603
	Expert E	normal	30	14.826
	Expert F	normal	31	22.239
	Expert G	lognormal	2.87	0.888
	Expert A	gamma	1.438	0.028

		Breeding season, dependents		
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
Common guillemot	Expert B	normal	50	37.065
	Expert C	beta	1.017	2.093
	Expert D	lognormal	0.886	1.603
	Expert E	normal	30	14.826
	Expert F	normal	17	11.861
	Expert G	beta	1.143	3.158
Kittiwake	Expert A	normal	50	44.478
	Expert B	normal	50	37.065
	Expert C	lognormal	2.708	1.028
	Expert D	lognormal	1.582	1.6
	Expert E	normal	10	7.413
	Expert F	normal	17	11.861
	Expert G	beta	1.294	2.204
Northern Gannet	Expert A	normal	30	22.239
	Expert B	normal	50	37.065
	Expert C	beta	1.017	2.093
	Expert D	lognormal	0.188	1.609
	Expert E	normal	10	7.413
	Expert F	normal	9	5.93
	Expert G	beta	1.032	3.41
Razorbill	Expert A	gamma	1.438	0.028
	Expert B	normal	50	37.065
	Expert C	lognormal	1.742	1.729
	Expert D	lognormal	0.886	1.603

Breeding season, dependents				
Species	**Expert**	**Distribution**	**Parameter 1**	**Parameter 2**
	Expert E	normal	20	14.826
	Expert F	t[1]	20.752	12.429
	Expert G	lognormal	2.303	1.028

[1] 3 degrees of freedom

6 Discussion and Future Research

6.1 The EE experience

The EE workshops were successfully conducted, despite not being through the preferred approach of intensive in-person workshops. This was a situation imposed by pandemic conditions, but ultimately did not hinder the EE objectives. The experts were well engaged with the process and there was lively discussion on displacement mortality and other related topics. No experts refused to participate once involved and a full set of estimates were provided.

While not preferable to field data from experiments, we do now have a collective expert view on possible parameter values, which importantly reflects several levels of scientific uncertainty. The process highlighted well existing knowledge gaps and suggestions for research priorities, while providing stop-gap parameter distributions that can find interim use where immediately necessary.

The online format was not optimal, as encouraging free discussion amongst the expert panel is more easily facilitated in person. Nonetheless, the experts on the panel provided excellent interaction, convinced of the need for the EE and the benefits it would bring, beyond the simple provision of estimate distributions. The online nature did provide some benefit, as some experts outside the UK might have been difficult to arrange in person – but some hybrid variant could provide more benefits. One main challenge for EEs is that they frequently rely on expert volunteers i.e. the give their time without recompense. This can create challenges in forming expert panels, although in this case almost all approached were forthcoming. This may become more of an issue if more EEs are sought in a similar area, as the group of experts may be called upon repeatedly.

6.2 Additional Research and Improvements to the Risk Assessment

At the end of the workshop, experts were asked to consider what aspects of seabirds' interactions with offshore wind farms had not been considered, particularly as it relates to the effects of displacement. The following summarises these points, along with topics emphasized by the panel during the entire workshop process.

The following research topics were highlighted by experts:

- Displacement effects of OWF go beyond simple mortality as being captured by DMR in this elicitation, for example impact on productivity was identified. The effects of habituation were discussed and were noted as potentially important but poorly known. Habituation was noted as being potentially positive in terms of sub-lethal effects (lower stress) and potential influences on collision rates.

- The values currently used in the assessments for the size of the populations that might be affected by DMR are noted as being under-estimates, being based on snapshots, perhaps limited to OWF footprints and near surrounds. The panel was clear that in reality much larger numbers will be interacting with OWF and subject to effects, e.g., different birds are passing through over time. While the numbers of birds expected to be affected by OWF were not a direct focus of the elicitation process, the DMR figures are likely to be combined with estimates of the number of birds influenced by an OWF for overall impact estimates. These estimates of numbers of birds will themselves be based on survey data, and therefore subject to the noted underestimation. Improved methods for estimating the number of birds subject to OWF influence was therefore identified as warranting research.

- Mature breeding birds and their dependents were considered here. It was noted that there are other classes of bird that might undergo differing displacement effects. "Sabbatical" adults and juveniles being two that were identified. Further research would be warranted for a more holistic view of displacement effects on a population.

- There were six species considered as part of this EE process. The scope was limited to a priority list for good logistical reasons, but other species were noted as being of potential importance. Further research of displacement effects for other species is warranted.

- Currently the cumulative effect of multiple windfarms is done in a simplistic additive fashion, i.e., calculations are done for individual wind-farms, then treated as independent by performing what is effectively a summation. The consequence of this is not clear, but overly simplistic: on one hand there will be double-counting of effects in some circumstances (e.g., a bird that dies at one wind farm cannot die at another), while on the other hand there is the potential to underestimate effects on an individual level (e.g., accumulated stress from interacting with multiple wind farms may increase exponentially, not linearly, as assumed by the summation). This was noted a complex issue warranting research for a deeper understanding and improved approaches for its treatment.

The following information to improve assessments was identified by experts:

- When considering displacement mortality rate (DMR), it was deemed important to consider the effects on dependents, not just the mature animals who are directly displaced. This is of principal importance within the breeding season. The importance of this is evidenced in the expansion of the initial elicitation scope from 11 questions to 16 to include the DMR for dependents – meaning an additional question for each of puffins, guillemot, kittiwake, gannet and razorbills. The experts noted that this difference between individuals and their dependents should be applied generally when determining DMR for OWF developments.

- More realistic estimates of the numbers of birds within the influence of an OWF, compared to those thought to be currently employed, are needed.

6.3 Future Directions

Part of the intent of an expert elicitation is to temporarily fill in knowledge gaps so that decisions can be made even as the proper empirical data are being collected. The purpose of this workshop was to aid UK regulators in their assessment process when considering the displacement impacts of offshore wind farms on seabirds. While it will require additional work on behalf of the organizations involved, the questions informing displacement mortality rates can be used to inform and update the approaches and values used within this assessment process.

An important component of the elicitation is that it captures the uncertainty around the experts' judgements, and this uncertainty [2] can be directly incorporated into the assessment process moving forward. For instance, when displacement impacts are estimated this uncertainty can be captured through simulation in the assessment tools, whereby values for displacement mortality rate can be drawn from the experts' probability distributions. This is repeated, often thousands of times, with each iteration drawing a different value from the experts' probabilistic judgements. In doing so, the experts' uncertainty is also captured and included in the assessment. Another approach that could be taken would be a sensitivity analysis exploring how the outcomes of the models may change at different quantiles of the experts' distributions. For example, the best, worst, and most likely scenarios for displacement mortality could be defined from the experts' 5th, 50th and 95th quantiles. This would then provide a range of potential impacts to consider that directly acknowledges and incorporates the experts' uncertainty into the assessment.

[2] Uncertainty expressed by the experts notably captures general uncertainty about basic mortality increase for an individual, subject to OWF influence, but also the wider range of potential influence scenarios. For example, experts noted they considered varying types of windfarms and their relationships with bird populations in their estimations, such as large/small OWF that are near/far from a bird colony.

7 References

Aspinall, W.P. (2006) Structured elicitation of expert judgement for probabilistic hazard and risk assessment in volcanic eruptions. In: Statistics in Volcanology, Mader HM, Coles SG, Conner CB and Conner LJ, eds. Special publications of IAVCEI No. 1. London.

Cains, M.G., Flora, L., Taber, D., King, Z. and Hensel, D.S. (2021) Defining cyber security and cyber security risk within a multidisciplinary context using expert elicitation. Risk Analysis, doi: 10.1111/risa.13687

Chang, W., Cheng, J., Allaire, J.J., Sievert, C., Schloerke, B., Xie, Y., …, Borges, B. (2021) shiny: Web Application Framework for R. Version 1.6.0 https://CRAN.R-project.org/package=shiny

CMST. (2020a) Soundscape Monitoring at the Jansz-Io Compression (JIC) Site January – December 2019. Unpublished report for Chevron Energy Technology Pty Ltd. CMST 1537 / Report 2019-15c, 5 April 2020.

CMST. (2020) Source Spectrum and Received Level Modelling for Underwater Noise Radiation from the Proposed Jansz-Io Compression (JIC) Facility. Unpublished report for Chevron Energy Technology Pty Ltd. CMST Report 2021-04, March 2021.

Commonwealth of Australia (2015) Conservation Management Plan for the Blue Whale—A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999, Commonwealth of Australia 2015.

Dallow, N., Best, N. and Montague, T.H. (2018) Better decision making in drug development through adoption of formal prior elicitation. Pharmaceutical Statistics, 17, 301-316.

DeRuiter, S.L., Southall, B.L., Calambokidis, J., Ximmer W.M.X., Sadykiva, D., Falcone, E.A., Friedlander, A., Joseph, J.E., Moretti, D., Schorr, G.S., Thomas, L., & Tyack, P. (2013) First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. (2013) Biology Letters, 9, doi: 10.1098/rsbl.2013.0223

Erbe, C., Dunlop, R., & Dolman, S. (2018) Effects of noise on marine mammals. In: Slabbekoorn H., Dooling R., Popper A., Fay R. (eds) Effects of Anthropogenic Noise on Animals, Springer Handbook of Auditory Research, vol 66. Springer, New York, NY, pp. 277-309.

Gerber, L.R., and Heppell, S.S. (2004) The use of demographic sensitivity analysis in marine species conservation planning. Biological Conservation, 120, 121-128.

Gosling, J.P. (2018) SHELF: the Sheffield elicitation framework. In: Elicitation, Dias LC, Morton A and Quigley J, eds. Springer International. Switzerland.

Hall, A.J., McConnell, B.J., Rowles, T.K., Aguilar, A., Borrell, A., Schwacke, L., Reijnders, P.J.H., and Wells, R.S. (2006) Individual-based model framework to assess population consequences of polychlorinated biphenyl exposure in bottlenose dolphins. Environmental Health Perspectives, 114, 60-64.

Hanea, A. M., McBride, M. F., Burgman, M. A., and Wintle, B. C. (2016). Classical meets modern in the IDEA protocol for structured expert judgement. Journal of Risk Research, 1–17, doi: 10.1080/1 3669877.2016.1215346.

Hemming, V., Burgman, M.A., Hanea, A.M., McBride, M.F. and Wintle, B.C. (2017) A practical guide to structured expert elicitation using the IDEA protocol. Methods in Ecology and Evolution, 9, 169-180.

Hogarth, R.M. (1975) Cognitive processes and the assessment of subjective probabilities. Journal of the American Statistical Association, 70, 271–289.

IUCN. (2012) IUCN red list catergories and criteria: Version 3.1. pp. iv + 32 pp. IUCN, Gland, Switzerland and Cambridge, UK.

King, S.L., Schick, R.S., Donovan, C., Booth, C.G., Burgman, M., Thomas, L. and Harwood, J. (2015) An interim framework for assessing the population consequences of disturbance. Methods in Ecology and Evolution, 6, 1150-1158.

Knol, A.B., de Hartog, J.J., Boogaard, H., Slottje, P., van der Slujis, J.P., Lebret, E., …, Hoek, G. (2009) Expert elicitation on ultrafine particles: likelihood of health effects and causal pathways. Particle and Fibre Toxicology, 6, 19, doi: 10.1186/1743-8977-6-19.

Mastrandrea, M. D., Field, C. B., Stocker, T. F., Edenhofer, O., Ebi, K. L., Frame, D. J., … Zweirs, F. W. (2010). Guidance note for lead authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. Jasper Ridge, CA

Nevalainen, M., Helle, I. and Vanhatalo, J. (2018) Estimating the acute impacts of Arctic marine oil spills using expert elicitation. Marine Pollution Bulletin, 131, 782-792.

New, L., Clark, J., Costa, D., Fleishman, E., Hindell, M., Klanjšček, T., Lusseau, D., Kraus, S., McMahon, C.R., Robinson, P.W., Schick, R.S., Schwarz, L.K., Simmons, S.E., Thomas, L., Tyack, P.L., & Harwood, J. (2014) Using short-term measures of behaviour to estimate long-term fitness of southern elephant seals. Marine Ecology Progress Series, 496, 99–108.

Nowacek, D.P., Thorne, L.H., Johnston, D.W., & Tyack, P. (2007) Responses of cetaceans to anthropogenic noise. Mammal Review, 37, 81-115.

O'Hagan, A., Buck, C.E., Daneshkhah, A., Eiser, J.R., Garthwaite, P.H., Jenkinson, D.J., Oakley, J.E. and Rakow. T. (2006) Uncertain Judgements: Eliciting Experts' Probabilities. Wiley. ISBN: 978-0-470-02999-2.

Jeremy Oakley (2021). SHELF: Tools to Support the Sheffield Elicitation Framework. R package version 1.8.0.

https://CRAN.R-project.org/package=SHELF

Oakley J. E. and O'Hagan, A. (2019). SHELF: the Sheffield Elicitation Framework (version 4). School of Mathematics and Statistics, University of Sheffield, UK. (http://tonyohagan.co.uk/shelf)

Pirotta, E., Booth, C., Costa, D., Fleishman, E., Kraus, S., Lusseau, D., Moretti, D., New, L.F., Schick, R., Schwarz, L., Simmons, S., Thomas, L., Tyack, P., Weise, M., Wells, R. and Harwood, J. (2018) Understanding the population consequences of disturbance. Ecology and Evolution, 8: 9934-46

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Sutherland, W.J., Armstrong-Brown, S., Armsworth, P.R., Tom, B., Brickland, J., Campbell, C.D., … Watkinson, A.R. (2006). The identification of 100 ecological questions of high policy relevance in the UK. Journal of Applied Ecology, 43, 617–627.

Sutherland, W.J., Freckleton, R.P., Godfray, H.C.J., Beissinger, S.R., Benton, T., Cameron, D. D., … Wiegand, T. (2013). Identification of 100 fundamental ecological questions. Journal of Ecology, 101, 58–67.

Taylor, B.L., Wade, P.R., De Master, D.P. and Barlow, J. (2000) Incorporating uncertainty into management models for marine mammals. Conservation Biology. 14, 1243-1252.

Threatened Species Scientific Committee. (2015) Conservation Advice Megaptera novaeangliae humpback whale. Canberra, Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservation-advice-10102015.pdf

Time, N.P. and Torpe, H. (2016) Subsea compression – Åsgard subsea commissioning, start-up and operational experiences. Paper presented at the Offshore Technology Conference, Houston Texas, USA. DOI: 10.4043/27163-MS.

Tversky, A. and Kahneman, D. (1974) Judgement under uncertainty: heuristics and biases. Science, 185, 1124–1131.

Usher, W. and Strachan, N. (2013) An expert elicitation of climate, energy and economic uncertainties. Energy Policy, 61, 811-821.

8 Appendix 1 – Workshop Participants, Roles and Declarations of Interest/Expertise

8.1 Additional invitees

The experts involved within the workshops are presented below. Other experts were approached, but either declined/were unable to attend, or did not respond to requests. These are listed here:

Name	Affiliation	Outcome
Sue O'Brien	Marine Scotland Science	Declined, and suggested who would be better suited.
Volker Dierschke	Consultant - Gavia EcoResearch	Did not respond in time.

8.2 Summary Table

Name	Affiliation	Role	Declaration of interests	Participant expertise[3]
Julie Miller	Marine Scotland Science	Expert	Not declared.	Senior ornithologist within the Renewable Energy and Environmental Advice Group, assessing seabirds in the context of offshore renewable impacts. Research focuses on the quantification of seabird demographic processes, the underlying drivers of population regulation and the potential for management

[3] Paraphrased in some cases from expert enquiry forms.

Name	Affiliation	Role	Declaration of interests	Participant expertise[3]
				intervention to preserve vulnerable species and populations. Previous works include impact of disturbance to seabirds on remote islands; the distribution, behaviour and condition of seabirds foraging in the Mid-Atlantic; and the foraging and breeding behaviour of large gulls.
Maria Bogdanova	UK CEH	Expert	None declared	An animal Population Ecologist at UKCEH. PhD and post-doctoral research at the University of Glasgow. 15 years' experience of research on seabird ecology – current focus on drivers of change in seabird populations, in particular the effects of environmental and demographic variation and direct human impacts on foraging ecology, movements and spatial distributions. Multiple industry/government projects on the effects of offshore wind developments on seabirds.
Adam Butler	BIOSS	Scientific advisor	N/A	Environmental statistician with BioSS.
Aonghais Cook	BTO	Expert	Received funding from offshore wind developers, the Crown Estate and others with an interest in the offshore wind industry.	Principal Ecologist (Offshore Renewable Energy) in the BTO Wetland and Marine Research Team. Leads BTO research on renewable energy with a particular focus on offshore wind farms. In addition to our work in the UK, provides advice about the potential impacts of offshore wind farms on seabird populations in the US, Japan and Australia.
Francis Daunt	UK CEH	Expert	Not declared.	Group Leader of the Coastal Seas Ecology Group at CEH and leads the long term study of seabird populations on the Isle of May. Extensive research and publication record regarding seabirds. Recipient of the BTO's Marsh

Name	Affiliation	Role	Declaration of interests	Participant expertise[3]
				Award for Ornithology for significant contributions to the understanding of UK's seabirds.
Carl Donovan	DMP Statistical Solutions UK Ltd.	Coordinator	Statistical and ecological methodology.	Statistician. Ecological modelling and analysis for expert elicitations.
Tom Evans	Marine Scotland Science	Expert	Not declared.	Senior Marine Ornithologist at Marine Scotland Science.
Jude Lane	RSPB	Expert	None declared	Expertise in seabird tracking, specifically northern gannets. PhD (University of Leeds) focused on the three-dimensional foraging behaviour of northern gannets breeding on the Bass Rock. Subsequent study of initial movements and first migration of juvenile gannets from the Bass Rock. RSPB, providing science support for casework on OFW. Ongoing Bass Rock gannet tracking work focused on breeding gannet's response to offshore turbines during incubation and chick-rearing.
Mardik Leopold	Wageningen University and Research	Expert	Not declared.	Marine Biologist at Wageningen Marine Research. Researcher in the ecological aspects of birds, marine mammals and their prey, providing ecosystem evaluations for the Dutch government and advisory projects on the future implementation of the EU Birds and Habitat Directive, on the Dutch Continental Shelf of the North Sea.

Name	Affiliation	Role	Declaration of interests	Participant expertise[3]
Aly McCluskie	RSPB	Expert	Not declared.	Senior Conservation Scientist. Provides scientific research and review for policy and casework relating to the effective conservation of protected sites – in particular the interactions between wind farms, both terrestrial and offshore, and birds. Extensive experience in working with upland raptors and seeking solutions to conflicts between such predators and man.
Leslie New	Ursinus College	Facilitator	Interest in expert elicitation.	Expert elicitation, effect of noise on marine mammals.
Kate Searle	UK CEH	Project manager/scientific advisor	N/A	Ecological modeller at CEH. Research focuses on the effects of environmental change on wildlife behaviour, populations and distributions.
Floor Soudijn	Wageningen University and Research	Expert	I have personal interest in the outcome of this elicitation exercise as an employee and a researcher.	Marine ecologist at Wageningen Marine Research (Netherlands). Study the effects of anthropogenic disturbance (e.g. sound exposure, fishing, offshore wind) on seabirds, fish and zooplankton with population models, food chain models and agent-based models. Background in theoretical ecology and marine ecology. PhD/Post-doc focusing on the structuring role of seasonality in population processes on predator-prey and food chain dynamics using physiologically structured models of fish and zooplankton. MSc studying subtidal invertebrate communities in manipulative field experiments. Recent projects focus on the effects of OWF on seabirds e.g. IBMs estimating displacement mortality for

Name	Affiliation	Role	Declaration of interests	Participant expertise[3]
				Common Guillemot, Razorbill, Northern Gannet, Sandwich Tern and Red-throated Diver. Developed/applied population models of these species estimating population level displacement effects. Research leader for recent impact assessment of future wind development plans at the Dutch continental shelf for the Dutch government.
Martin Perrow	ECON Ecological Consultancy Ltd	Expert	Not declared.	Director of ECON Ecological Consultancy Ltd and currently manages the ornithological requirements of several wind farm sites, assessing the likely impacts and providing advice in order to engineer the co-existence of birds and wind farms with minimal impacts. Extensive research and publication record with regards wildlife interactions with wind-farms.

8.3 Expert Enquiry Forms

8.3.1 Example Expert Enquiry Form

The Expert Enquiry forms provided to the experts were a template available as part of the SHELF package (Oakley and O'Hagan 2019). The package, and all the templates and slides provided therein, is made freely available, although it is covered by copyright. The authors permit use for elicitations, private study and personal use, but the information and provided materials may not be reproduced on any website, offered for sale, or otherwise distributed without their written permission.

Expert Enquiry Form

Dear expert, thank you very much for agreeing to take part in an expert elicitation workshop. The combined knowledge of the experts in the workshop, based not only on the available relevant evidence but also on their experiences and expertise, will play a vital part in our work.

In order for us to prepare properly for the workshop, and not to waste time covering things that can be dealt with in advance, we ask you to complete this enquiry form.

1) Name and title	**Please write your name, including your title, below. In the report of the workshop, the names of all the experts will be listed. However, any opinions expressed during the workshop will be reported in an anonymised way.**
2) Background and expertise	Please provide us with a short description of your background, including your current employer and position. Please also tell us about your expertise relating to the workshop topics. This information will be given to the other participants in the workshop, to assist in the discussions. It will also be included in the workshop report, to document the high quality of expertise that has contributed to its findings.
3) Declarations of interests	Please identify any personal interest that you might have in the outcome of this elicitation exercise – whether as an employee, consultant, shareholder or in any other capacity. We recognise that most experts will have some interest to declare, and this does not in any way exclude people from taking part in the workshop. However, for reasons of openness, the workshop report will also include the experts' responses to this question.
4) Additional evidence	We have sent you our "evidence dossier", which describes the evidence base, as it is known to us, for the topics of this workshop. It is important that all relevant evidence is considered in the workshop, so please list here any additional sources that we should be aware of, or that you may wish to refer to in the workshop. Please provide full citations.
5) Clarifications and corrections	If you have any other suggestions or questions regarding the evidence dossier, please list them here. We particularly wish to know if anything needs clarifying or correcting.

9 Appendix 2 – Workshop Agendas

The following are the proposed agendas for the workshops. Given the interactive nature of the workshops, these are subject to change to meet the expert's needs. Deviations are noted below.

The facilitator (Dr New) provided presentations about the expert elicitation process. Scientific advisors from UK CEH (Dr Searle) and BIOSS (Dr Butler) provided presentations giving specific background to this elicitation.

Day 1 [10:00 – 13:00 GMT]

10:00 – 10:05: Opening statements [*Facilitator*]

10:05 – 10:20: Introductions [*All*]

10:20 – 10:45: Overview of Project [*Scientific advisors UK CEH & BIOSS*]

10:45 – 10:55: Break

10:55 – 11:20: Intro to EE [*Facilitator*]

11:20 – 11:30: Management/Legal Background [*Scientific advisors UK CEH & BIOSS*]

11:30 – 11:50: Modelling Background [*Scientific advisors UK CEH & BIOSS*]

11:50 – 12:00: Break

12:00 – 12:10: Approach to Elicitation [*Facilitator*]

12:10 – 12:40: Details of EE [*Facilitator*]

12:40 – 12:50: Discussion of Elicitation Questions [*All*]

12:50 – 13:00: Day 1 Closure [*Facilitator*]

[**Deviation** extensive discussions led to planned items (grey) after 12pm being moved to start of day 2]

Day 2 [10:00 – 13:00 GMT]

10:00 – 10:20: Recap, issues arising [All]

10:20 – 10:45: Intro to EE [*Facilitator*]

10:45 – 10:55: Break

10:55 – 11:10: Approach to Elicitation [*Facilitator*]

1110: – 11:40: Details of EE [*Facilitator*]

11:50 – 12:00: Break

12:00 – 12:15: Presentation of EE app [*Facilitator*]

12:15 – 12:50: Discussion of Elicitation Questions [*All, including slides from UK CEH and BIOSS*]

12:50 – 13:00: Day 2 Closure [*Facilitator*]

Day 3 [10:00 – 13:00 GMT]

10:00 – 10:10: Review [*Facilitator*]

10:10 – 10:50: Review of expert judgements [*All*]

10:50 – 11:00: Break

11:00 – 11:50: Review of expert judgements [*All*]

11:50 – 12:00: Break

12:00 – 12:50: Review of expert judgements [*All*]

12:50 – 13:00: Day 3 Closure [*Facilitator*]

Day 4 [10:00 – 13:00 GMT]

10:00 – 10:10: Review [*Facilitator*]

10:10 – 10:50: Review of expert judgements [*All*]

10:50 – 11:00: Break

11:00 – 11:50: Review of expert judgements [*All*]

11:50 – 12:00: Break

12:00 – 12:50: Review of expert judgements [*All*]

12:50 – 13:00: Day 3 Closure [*Facilitator*]

10 Appendix 3 – Elicitation Process

10.1 Process

The elicitation was conducted using the Sheffield Elicitation Framework (SHELF), the basis of which was first outlined in O'Hagan et al. (2006) and uses probability distributions to represent expert judgements. The elicitation of these distributions was done used the quartile method, in which experts are asked to provide five values: the lowest and highest plausible values, the median, first quartile and third quartile. As a result, the experts were never asked to provide single estimates of any quantities of interest. Instead, the method seeks to identify a plausible range of values and which values within that range are more likely. Experts will have uncertainty around the quantities they are being asked to estimate. This uncertainty will be directly reflected in the outputs of the elicitation and is a key component of the information being captured. In addition, SHELF uses the Delphi process (Delbecq et al. 1975), which asks experts to reconsider their judgements in light of discussion with other experts and has been shown to improve the reliability of results from an expert elicitation process (Burgman et al. 2011).

The SHELF process, using the quartile methods, can be summarized as follows

1) Identify the knowledge gaps and quantities of interest that will be elicited
2) Provide experts with an evidence dossier prior to the workshop
3) Review any relevant information in the workshop itself
4) Take the following steps for each quantity of interest:
    i. Review the question with the experts, ensuring that the experts understand the quantity that is being elicited and are in general agreement as to what value is being requested. This also provides an opportunity for experts to bring up additional, relevant information that may not have been discussed previously.
    ii. Ask the experts to provide the range of plausible values for the quantity of interest in the form of a lower (L) and upper (U) plausible bound. The objective is to identify a range such that it is extremely unlikely, but not impossible, that the value of interest (X), falls outside the specified range.
    iii. After defining the plausible range, the experts must specify their median (M) value for the quantity of interest. The median is a value such that it is equally likely that X above or below M, i.e., $P(X<M) = 0.5$. Therefore, if the experts were asked to place a bet as to which side of M X would fall, they should not have a preference as to which side they choose.
    iv. Next, the experts are asked to specify their lower quartile (Q1). This is done by considering just the range from L to M, and dividing it into two equally likely intervals, such that there is a 25% chance that X will fall

on either side of Q1, i.e., $P(L < X < Q1) = P(Q1 < X < M) = 0.25$. The same approach should be taken when the experts specify their upper quartile (Q3), but now dividing the range from M to U into two equally likely intervals, i.e., $P(M < X < Q3) = P(Q3 < X < U) = 0.25$. It should be noted that Q1 and Q3 are generally closer to M than to the plausible bounds, and that the size of the four ranges (L to Q1, Q1 to M, M to Q3, Q3 to U) need not be of equal width.

v. Before deciding on their values, experts are asked to check that each of the four ranges (L to Q1, Q1 to M, M to Q3, Q3 to U) is equally likely, and that X is as equally likely to fall within the range of Q1 to Q3 as outside of it.

vi. Once all the experts have submitted their upper and lower plausible bounds, medians and quartiles, the analyst fits a distribution to the experts' assessments. This is done using the SHELF package (Oakley 2020) in the statistical computing program R (v. 4.1.0, R Core Team 2021), which chooses the distribution and parameters that give probabilities matching the elicited bounds, median and quartiles as closely as possible.

vii. The distributions are then shown to the experts and discussed, with the facilitator pointing out any logical inconsistencies or lack of coherence with the elicited distributions. The experts are encouraged to share knowledge and reasoning about the differences that are observed, as well as provide the potential logic behind the distributions they are observing, regardless of whether they believe it was the one they specified. Experts are then given an opportunity to revise their values based upon the discussion.

viii. After the revised values have been submitted the analyst fits a distribution to the experts' revised assessments, and the new distributions are shown to the experts. At this point, a linear pool of the experts' distributions can be shared and the experts asked to determine whether this distribution, or another that would need to be specified, accurately reflects the conversations and beliefs that have been expressed with regards to the quantity of interest.

5) Throughout the workshop a record is kept of the iterative process of eliciting experts' judgements, fitting distributions, receiving feedback and revision of the experts' assessments. This record also includes any difficulties that arose during the elicitation and the experts' reaction to the process.

The nature of expert elicitation is inherently subjective, making it important to ensure that the elicitation process is as transparent as possible. This is done, in part, by keeping a detailed record of the workshop (sections 12 to 15), including all discussions and knowledge sharing. In addition, there is a record of all individuals to attend the workshop, including their affiliation, role, relevant expertise and any declaration of interest (section 8). Declarations of interest are recorded for the purposes of transparency, and are not grounds for exclusion from the elicitation.

An evidence dossier (Appendix 4 – Evidence Dossier) was supplied to all experts prior to the workshop.

10.2 References

Burgman, M. A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., et al. (2011). Expert status and performance. PloS one, 6(7), e22998. doi:10.1371/journal.pone.0022998.

Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, Allen J, McPherson J, Dipert A, Borges B (2022). *shiny: Web Application Framework for R*. R package version 1.7.3, <https://CRAN.R-project.org/package=shiny>.

Delbecq, A., Van de Ven, A., & Gustafson, D. (1975). Group techniques for program planning: a guide to nominal group and Delphi processes. Glenview, IL: Scott, Foresman and Company.

O'Hagan, A., Buck, C.E., Daneshkhah, A., Eiser, J.R., Garthwaite, P.H., Jenkinson, D.J., Oakley, J.E. and Rakow. T. (2006) Uncertain Judgements: Eliciting Experts' Probabilities. Wiley. ISBN: 978-0-470-02999-2.

Oakley, J. E., & O'Hagan, A. (2019). SHELF: the Sheffield elicitation framework. Version 4. School of Mathematics and Statistics. University of Sheffield, United Kingdom. Available from http://tonyohagan. co. uk/shelf (accessed February 2020).

Oakley J (2021). *SHELF: Tools to Support the Sheffield Elicitation Framework*. R package version 1.8.0, <https://CRAN.R-project.org/package=SHELF>.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Searle, K., Mobbs, D., Butler, A., Bogdanova, M., Freeman, S., Wanless, S., & Daunt, F. (2014). Population Consequences of Displacement from Proposed Offshore Wind Energy Developments for Seabirds Breeding at Scottish SPAs (CR/2012/03): *Final Report to Marine Scotland Science. Marine Scotland Science*.

Searle, K. R., Mobbs, D. C., Butler, A., Furness, R. W., Trinder, M. N., & Daunt, F. (2018). Finding out the fate of displaced birds. *Scottish Mar. Freshw. Sci*., 9, 149.

Searle, K., Butler, A., Bogdanova, M., & Daunt, F. (2020). Scoping Study-Regional Population Viability Analysis for Key Bird Species CR/2016/16. Scottish Marine and Freshwater Science, 11(10).

11 Appendix 4 – Evidence Dossier

11.1 Dossier circulated to experts

PDF
ORJIP_QuMR_WP1_
Displacement mortal

11.2 Information identified as missing in dossier

The Expert Enquiry forms provided a field for them to highlighting where information was missing from the dossier. These are presented below.

For the population level assessment of effects of offshore wind farms on seabirds, a new method of 'acceptable levels of impact' was recently developed for the Dutch government:

Potiek, A., G. IJntema, T. van Kooten, M. F. Leopold, and M. P. Collier. 2021. Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species. A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss. Bureau Waardenburg Report 21-0120, Bureau Waardenburg, Culemborg, The Netherlands.

In 2022, two reports were finalized that describe the population level effects of international and Dutch future offshore wind farms on a range of (sea) bird species, for both displacement mortality:

Soudijn, F. H., S. van Donk, M. F. Leopold, J. T. van der Wal, and V. Hin. 2022. Cumulative population-level effects of habitat loss on seabirds 'Kader Ecologie en Cumulatie 4.0.' Wageningen Marine research report C007/22, Wageningen Marine Research, IJmuiden. DOI: 10.18174/565601

and collision mortality:

Potiek, A., J. J. Leemans, R. P. Middelveld, and A. Gyimesi. 2022. Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea. Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0. Bureau Waardenburg Report, 21-205, Bureau Waardenburg, Culemborg.

Wildlife and Wind Farms, Offshore: Potential Effects. CHAPTER 8 Seabirds: displacement. NICOLAS VANERMEN and ERIC W.M. STIENEN

While the exclusion of these documents from the dossier means that the information contained therein was not available to all participants in written form, the experts who provided these references were in a position to bring any relevant content to the attention of the workshop attendees.

12 Displacement Mortality Expert Elicitation Record - Workshop 5th May

All workshops were extensively minuted, but these are not presented in full here. Following are the attendance records, high-level summary of the proceedings and a distillation of the minutes to those points deemed important.

Note there were two groups of attendees for the workshops: 1) the experts & project team members (the panel), and b) observers (the gallery). The former of these was able to interact fully with other workshop attendees (audio, video, reactions and chat). The latter had viewing privileges only, i.e., they could not interact directly with the panel in any way. Any interactions with the panel were to be directed through the facilitator, although no observer reached out in this manner.

12.1 Participants List:

Name	Initials	Role
Leslie New	LN	SHELF facilitator
Carl Donovan	CD	SHELF statistics/analysis
Kate Searle	KS	Project team – advising on project background
Adam Butler	AB	Project team – advising on project background
Floor Soudijn	FS	Expert
Julie Miller[4]	JM	Expert
Mardik Leopold	ML	Expert
Jude Lane	JL	Expert
Martin Perrow	MP	Expert
Francis Daunt	FD	Expert
Aonghais Cook	AC	Expert
Maria Bogdanova	MB	Expert
Aly McCluskie	AM	Expert

[4] Julie Miller was present in lieu of Tom Evans the first workshop due to conflicting commitments.

In addition, for this workshop 11 unique logins were logged for the observers gallery, noting the stream may be observed by multiple people at the same computer.

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12.2 Overview

- [Workshop begins after 10am scheduled start, due to confusion with zoom links]
- Introductions
- Project overview presentation from KS. Presentation concludes after first scheduled break – circa 11:20.
- Extensive discussion about what the fundamental question is, and how it ought to be worded.
- AB gives presentation on technicalities of displacement in assessment tools – circa 12:10 – 12:20.
- Further discussion about what the fundamental question is, and how it ought to be worded.
- Draft question wording proposed.
- Extensive discussion about considering dependents in the breeding season.
- Two versions of question wording proposed, increasing the scope to cover dependents in the breeding season, and the mature individuals in the breeding or non-breeding seasons.

12.3 Comments on Workshop Minutes/Notes

Experts are represented anonymously, unless the expert was presenting information in which case they were identifiable.

- Ecosystem-level effects are not accounted for, only direct collision and displacement of the birds in question.
- Displacement is not just in terms of foraging location (albeit important), but aversion adding energetic costs.
- Influence of a OWF is broader than the defined foot-prints, e.g., construction activities, maintenance and cable corridors.

- A draft wording proposed reflecting the effects are from the “influence” of OWF.
- There is agreement that it is important that DMR ought to consider dependents in the breeding season, not just the animals directly displaced.
- A refinement of wording proposed that considers dependents.
- Assessments over multiple OWFs are treated as additive, i.e., assessments done for individual OWF, then would be added for consideration of cumulated effect from multiple windfarms – which permits double counting of effects.
- Number of birds considered to be at risk in displacement calculations will be an underestimate, as they are based on estimated densities typically taken as a snapshot from a survey. Broad agreement on this.

12.4 Presentations

1) Project overview [from KS]

EE summary slides.pdf

2) Use of parameters [from AB]

EE technical use of Disp tools Final.pdf

13 Displacement Mortality EXPERT ELICITATION RECORD – Workshop 13th May

All workshops were extensively minuted, but these are not presented in full here. Following are the attendance records, high-level summary of the proceedings and a distillation of the minutes to those points deemed important.

Note there were two groups of attendees for the workshops: 1) the experts & project team members (the panel), and b) observers (the gallery). The former of these was able to interact fully with other workshop attendees (audio, video, reactions and chat). The latter had viewing privileges only, i.e., they could not interact directly with the panel in any way. Any interactions with the panel were to be directed through the facilitator, although no observer reached out in this manner.

13.1 Participant List

Name	Initials	Role
Leslie New	LN	SHELF facilitator
Carl Donovan	CD	SHELF statistics/analysis
Kate Searle	KS	Project team – advising on project background
Adam Butler	AB	Project team – advising on project background
Jude Lane	JL	Expert
Francis Daunt	FD	Expert
Aonghais Cook	AC	Expert
Maria Bogdanova	MB	Expert
Floor Soudijn	FS	Expert
Mardik Leopold	ML	Expert
Tom Evans	TE	Expert
Martin Perrow	MP	Expert
Aly McCluskie	AM	Expert

In addition, for this workshop, 6 unique logins were logged for the observers gallery, noting the stream may be observed by multiple people at the same computer.

13.2 Overview

- Discussion of points arising from previous workshop.
- Three presentations on Expert Elicitations (EEs) [from facilitator LN]. These occupied the first half of the workshop – completing 11:30am, comprising of:
    - EEs in general.
    - EEs in more detail.
    - EE specifics with regards values sought in this project.
- Discussion regarding the scope of DMRs. In particular, the temporal extent of this estimate.
- Presentation on the technical use of DMR estimates in assessment tools [from AB]
- Discussion on what the DMR parameter means and refinement of the question – a % increase in mortality for a bird that would otherwise have survived in absence of OWF.
- Further refined question(s) proposed.

13.3 Comments on Workshop Minutes/Notes

Experts are represented anonymously, unless the expert was presenting information in which case they were identifiable.

- There was a discussion on the confidentiality of discussion in light of the observer gallery, which some experts weren't fully aware of. The panel agreed that this was acceptable.
- LN gave a high-level presentation on EEs, covering rationale and precedence.
- There was a discussion about how disagreements between experts would be resolved within the process. Disagreements may be resolvable if based on different understanding of the question. Genuine disagreements are retained in the process, as reflects uncertainty.
- LN presented further on EEs.
- There was discussion about the scope of what the DMR parameter covers, e.g., should the experts be considering a single OWF, or many, differing sizes, location, etc.

- Discussion that the displacement effects might not be limited to mortality, e.g., productivity effects instead. Productivity was emphasized as potential route for impact.
- LN additional presentation on EEs at a more detailed level (completes approximately 1/2 -way through workshop circa 11:30).
- Discussion of the temporal extent of displacement effects. Noted that the consequences might be longer term, e.g., next breeding season.
- AB and KS provide additional slides as discussion points WRT technical use of displacement tools.
- Discussion how numbers of birds potentially affected by the OWF can be significant underestimates, as might be based on snapshots of OWF footprint abundances. Peak population size noted to be the advised figure to use, but under discussion elsewhere. Apportioning noted as also being broadly used. General dissatisfaction expressed by the panel about estimates that might be used for the numbers of birds that might be subject to increased DMR from an OWF.
- Current draft question text is presented and floor opened for discussion.
- More explicit wording on the effect metric to %-age increase in mortality. Spatial scope defined as birds that would have "used the area". Individuals versus a population discussed, with wording directed towards individuals as assessments address the numbers of birds being affected separately.
- The distinction between adults and chicks discussed and agreed as important. The splitting of these into individuals and "dependents" is agreed upon when estimating DMR within the breeding season.
- Some discussion about the implications of such a splitting in assessments as currently done. General agreement the biological reality is important, not necessarily how it would be used in practice – although noted that it would not be difficult to use in some current tools like PVAs.
- Some discussion about dependents and "inter-dependents".

13.4 Presentations

1) General EE presentation

Intro to EE.pdf

2) Detailed EE presentation

Details of EE.pdf

3) Project-specific EE presentation

Approach to EE.pdf

14 Displacement Mortality EXPERT ELICITATION RECORD – Workshop 17th May

All workshops were extensively minuted, but these are not presented in full here. Following are the attendance records, high-level summary of the proceedings and a distillation of the minutes to those points deemed important.

Note there were two groups of attendees for the workshops: 1) the experts & project team members (the panel), and b) observers (the gallery). The former of these was able to interact fully with other workshop attendees (audio, video, reactions and chat). The latter had viewing privileges only, i.e., they could not interact directly with the panel in any way. Any interactions with the panel were to be directed through the facilitator, although no observer reached out in this manner.

14.1 Participant List

Name	Initials	Role
Leslie New	LN	SHELF facilitator
Carl Donovan	CD	SHELF statistics/analysis
Kate Searle	KS	Project team – advising on project background
Adam Butler	AB	Project team – advising on project background
Floor Soudijn	FS	Expert
Mardik Leopold	ML	Expert
Tom Evans	TE	Expert
Martin Perrow	MP	Expert
Francis Daunt	FD	Expert
Aonghais Cook	AC	Expert
Aly McCluskie	AM	Expert
Maria Bogdanova	MB	Expert

In addition, for this workshop, 9 unique logins were logged for the observers gallery, noting the stream may be observed by multiple people at the same computer.

14.2 Overview

- Parameter estimates had been provided by several experts prior to the workshop. These were given preliminary analysis and presented as discussion points for the workshop.
- Delayed start to the workshop as facilitator was delayed.
- CD took facilitator role in LN absence. One question for which there was a high response rate was used as an example for discussion.
- Extensive discussions about possible rationales for the estimates presented, in an anonymous fashion (particular expert's estimates were not identified, unless by themselves).
- Confirmed the common understanding of the question and what the estimates being provided represent.

14.3 Comments on Workshop Minutes/Notes

Experts are represented anonymously, unless the expert was presenting information in which case they were identifiable.

- [Minuting sparse for initial part of workshop as facilitator absent]
- Initial discussion with LN encouraging experts to provide estimates for all questions. Several experts expressed discomfort as they were deeply uncertain for some species/time-periods. LN emphasized that the uncertainty has an avenue for expression through the parameter distributions, and that the EE process is being employed exactly because the figures aren't known.
- Longer break taken to allow experts to provide more estimates.
- Further expression of discomfort from experts about providing estimates for things which are so poorly known.
- Example output plots examined in detail, with particular focus on upper bounds, where greatest divergence in expert opinion was observed.
- Panel provided rationales/their thought processes when arriving at their estimates. Several members described using estimates of natural mortality as a benchmark for determining DMR, e.g., a natural mortality rate of 6%, the effect of an OWF would on the outside be 2-3x this mortality rate on top, so an upper bound of circa 20% additional mortality.

- Extensive discussion about whether the %-age figure was understood to be the same for all members. Most gave explicit agreement, although they may differ in their estimations.
- LN made observations that while the upper bounds did vary greatly in some cases, there was a general agreement in terms of the bulk of belief being towards lower values for DMR.
- An expert noted still having difficulty in picturing a generic OWF. The estimates might reflect the range of different sorts of OWF, where some would have a placement very detrimental to a colony, justifying a very broad view of possible DMR – whereas the “average” OWF might be mild.
- LN noted that the bounds capture this and high bounds could be justified on that basis. Further opened the floor for opinions on whether the beliefs were being captured – no objections voiced. A 4th workshop mooted.

15 Displacement Mortality EXPERT ELICITATION RECORD – Workshop 10th June

All workshops were extensively minuted, but these are not presented in full here. Following are the attendance records, high-level summary of the proceedings and a distillation of the minutes to those points deemed important.

Note there were two groups of attendees for the workshops: 1) the experts & project team members (the panel), and b) observers (the gallery). The former of these was able to interact fully with other workshop attendees (audio, video, reactions and chat). The latter had viewing privileges only, i.e. they could not interact directly with the panel in any way. Any interactions with the panel were to be directed through the facilitator, although no observer reached out in this manner.

15.1 Participant List

Name	Initials	Role
Leslie New	LN	SHELF facilitator
Carl Donovan	CD	SHELF statistics/analysis
Kate Searle	KS	Project team – advising on project background
Floor Soudijn	FS	Expert
Tom Evans	TE	Expert
Martin Perrow	MP	Expert
Aonghais Cook	AC	Expert
Maria Bogdanova	MB	Expert
Aly McCluskie	AM	Expert

In addition, for this workshop, 13 unique logins were logged for the observers gallery, noting the stream may be observed by multiple people at the same computer.

15.2 Overview

- Most experts have provided estimates a priori, which had been summarized and plotted for discussion.
- The workshop generally consisted of going through the results of each question in turn, with discussion on each. The first questions generated greatest discussion, with same points applying to later questions.
- Results for individual birds and dependents were markedly different, both types generating differing discussion.

15.3 Comments on Workshop Minutes/Notes

Experts are represented anonymously as 'Expert A' or 'Expert B' etc where multiple experts were discussing/responding, unless the expert was presenting information in which case they were identifiable.

- First example Atlantic puffin, breeding season, dependents shown first.
- Higher variability in responses, relative to the individual's results seen in the previous workshop.
- Queries/discussion over 100% upper bound suggested by some experts. Rationale being that dependent mortality is already high, so an additional 100% doesn't tally.
- Raises the question that an estimate of baseline mortality is particularly important to estimate these figures.
- Noted that opinions might depend markedly on one's experience with particular OWF. An opinion expressed that their experience led them to think all chicks dying was very plausible.
- Discussion that dependent mortalities are sensitive to the specifics of a windfarm.
- Atlantic individuals example – much greater agreement noted.
- Possibility of a positive effect noted again, e.g., a scenario that has a terrible effect on breeding, but the adults in fact do well/better as a result of the failure.
- Results for individual (i.e., not dependents) repeatedly noted as having general agreement over experts – bulk of belief is towards low DMR.
- The experts' responses to the DMR for Guillemot dependents in the breeding season initiated discussion about extreme bounds. Discussion about zero – general agreement in the results that zero (no impact) is plausible, but some disagreement. One expert noting that for dependents

very good and very bad scenarios are imaginable. One expert certain that there will always be some effect on dependents.

- Further discussion of upper bounds – some argument forwarded that the figure cannot be very high, unless subject to other stressors.
- Noted that it is not always the same (anonymous) experts that are being precautionary.
- Further noting of general agreement with questions regarding individuals (c.f. dependents). Some expert's exclusion of "no impact" as plausible queried again.
- Floor opened for additional points.

Additional points for explicit inclusion in the record

- Estimates are for the North Sea.
- Emphasis that habituation is not being considered here. This might come with beneficial effects.
- Displacement might be better than remaining within the OWF influence, e.g., stress. So sub-lethal effects greater for those who don't displace.
- The focus on individual windfarms highlighted again as a weakness. Currently simple cumulative approaches taken to consider in-combination effects. Not clear how you combine effects of multiple windfarms on a bird.
- The numbers of birds interacting with OWF again highlighted as greater than currently estimated, e.g., currently only a single temporal density peak is used.
- Only considered dependents and (mature) individuals. Juveniles potentially have a different response.
- Other species might be considered (noted that the scope is necessarily limited by the demands on experts for EEs).