**Supplementary material 1- Review of SEE guidelines**

We used the following inclusion criteria to identify SEE guidelines for our review:

1. Guidelines must be full-length (i.e., no conference abstracts), English-language documents published from 1990-2018.
2. Guidelines must focus on the structured elicitation of explicitly probabilistic judgements from experts (i.e., no papers primarily about eliciting rankings, paired comparisons, or other non-probabilistic information from experts).
3. Guidelines must offer recommendations for practice concerning more than one of the stages of an elicitation (i.e., design, preparation, conduct, and analysis).

SEE guidelines are published as scientific papers and as policy documents or other grey literature, so we adopted a broad search strategy designed to capture all relevant guidelines (Figure 1A). We searched Scopus and Web of Science for the period from 1990 to 2018 using the following keywords: “(expert AND (judgment OR judgement OR opinion) AND (elicit\*) AND (method\* OR protocol OR procedure OR guid\* OR technique)),” which yielded 827 results in Web of Science and 989 in Scopus. Results were screened based on the title and abstract. If a paper potentially met the inclusion criteria based on its title and abstract, the full-text source was reviewed. The references lists in each of the full-text articles were reviewed to identify additional possible guidelines.

**Figure 1A. Search results**



In some cases, multiple sources with the same or similar author lists provide very similar recommendations. For the purposes of this review, these sources are considered to be the same guidance, and only one version was included. The earliest complete version of the guidance that appeared was used, but references to the “duplicate” guidelines are included in the next section.

In the screening process, papers that focused on only one aspect of the elicitation process were excluded, such as how to encode judgements or fit judgements to distributions [e.g. 1, 2] Descriptions of software that did not discuss aspects of elicitation not managed within the software, were excluded[e.g. 3, 4] Reviews of past elicitation work or where experts can be used within a specific field were excluded, if they did not offer recommendations for practice.[e.g. 5, 6-8] Finally, cases studies that focused on the presentation of a set of results rather than a methodology for future work were excluded, [e.g. 9, 10]

**Extraction template**

For each of the included SEE guidelines, information was gathered on the elicitation process in an extraction template (Table 1A). This describes the elicitation process as pertaining to 3 stages: 1) preparation and design, 2) conduct and 3) post-elicitation. The extraction template was based on previous reviews of the elicitation process [11, 12] and was piloted and refined before use in this review.

**Table 1A. The extraction template.**

**Review**

|  |  |
| --- | --- |
| Source |  |
| Type of article |  |
| Domain |  |
| Self-reported objective |  |
| **Preparation and design** |
| What quantities to elicit? |  |
| Who/how many experts? |  |
| How to encode judgements? |  |
| How to manage biases? |  |
| How to approach validation? |  |
| Piloting the exercise |   |
| Training and preparation for experts |   |
| Training for other roles |   |
| **Elicitation** |
| Level of elicitation |   |
| Mode of administration |   |
| Feedback to experts & revision |   |
| Opportunity for interaction |   |
| Feedback from experts on process |   |
| Rationales |   |
| **Aggregation, analysis, and post-elicitation** |
| If/how to aggregate |   |
| Fit to distribution |   |
| Adjusting judgements |   |
| Documentation |   |

**Included SEE guidelines**

**Table 2A. The 16 guidelines included in the review and related sources identified in the search.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Reference** | **Related references** | **Domain** | **Type of article** |
| (Choy, O'Leary et al. 2009) [13] | (Martin, Burgman et al. 2012) [14] | Ecology | Review of evidence and/or practice |
| Classical Model(Cooke and Goossens 2000) [15] | (Cooke 1991, European Food Safety 2014, Quigley, Colson et al. 2018) [12, 16, 17] | Generic | Review of evidence and/or practice; Reflection on personal practice |
| EFSA Delphi(European Food Safety 2014) [16]1 |  | Food safety | Agency guidance |
| (EPA 2009) [18]2 |  | Environmental protection | Agency guidance |
| (Garthwaite, Kadane et al. 2005) [19] | (O'Hagan, Buck et al. 2006) [11] | Generic | Review of evidence and/or practice |
| IDEA protocol (Hemming, Burgman et al. 2018) [20] | Other descriptions of IDEA: (Hanea, McBride et al. 2016, Hanea, McBride et al. 2017, Hanea, Burgman et al. 2018) [21-23]Related reviews of elicitation practice in conservation, pre-dating development of IDEA: (Kuhnert, Martin et al. 2010, Martin, Burgman et al. 2012, Drescher, Perera et al. 2013) [14, 24, 25] | Generic | Review of evidence and/or practice; Reflection on personal practice |
| (Ashcroft, Austin et al. 2016) [26] |  | Insurance | Agency guidance |
| (Tredger, Lo et al. 2016) [27] |  | Insurance | Agency guidance |
| (Kaplan 1992) [28] |  | Risk and reliability | Reflection on personal practice |
| (Keeney and Vonwinterfeldt 1991) [29] | (Ortiz, Wheeler et al. 1991) [30] | Nuclear | Reflection on personal practice |
| (Knol, Slottje et al. 2010) [31] |  | Environmental health | Review of evidence and/or practice |
| (Meyer and Booker 2001) [32] |  | Generic | Review of evidence and/or practice |
| (Kotra, Lee et al. 1996) [33] | (Bonano, Hora et al. 1990) [34] | Nuclear | Agency guidance |
| (Budnitz, Apostolakis et al. 1997) [35] |  | Nuclear | Agency guidance |
| SHELF(Gosling 2018) [36] | (O'Hagan, Buck et al. 2006, European Food Safety 2014, O'Hagan and Oakley 2016) [11, 16, 37] | Generic | Review of evidence and/or practice; Reflection on personal practice |
| (Walls and Quigley 2001) [38] |  | Risk and reliability | Reflection on personal practice |

Notes:

1. The EFSA guideline covers three distinct elicitation methods: the Classical Model, EFSA Delphi, and SHELF. As the Classical Model and SHELF are presented in other guidelines, only the portions of the EFSA document related to the EFSA Delphi method are included in this review.
2. This guideline is a White Paper released for public review that was not intended to be the final agency report on the subject. However, a revised version responding to public feedback was never completed. Although this guideline says it is not final and should not be used as such, it is widely cited in elicitation literature and has served as a de facto guideline as nothing from the agency has yet superseded it.

**Table 3A. What quantities to elicit: Recommendations and choices from the guidelines**

|  |  |  |  |
| --- | --- | --- | --- |
| Component and choices | Recommendation | Choice | Recommended against |
| Type of parameter |
| Elicit observable quantities | [13, 15, 16, 19, 38] | [32, 35] |  |
| Elicit required model parameters directly (if sufficiently well understood) |  | [19, 32, 35] | [16] |
| Type of quantity |
| Proportions |  | [19] |  |
| Frequencies | [13, 15, 20] | [33] |  |
| Probabilities |  | [32, 33] | [13, 15] |
| Odds ratios |  | [32] |  |
| Selection criteria for quantities |
| Define selection criteria (probabilities, consequences, constraints, etc) | [29, 35] |  |  |
| Minimal assessment of each possible uncertain parameter and sensitivity analysis to see which uncertain parameters have the biggest impact | [16] |  |  |
| Principles for describing quantities |
| Ask clear and well-defined questions | [16, 26, 29, 31, 36] |  |  |
| Ask questions in a manner consistent with how experts express their knowledge | [13, 15, 16, 18, 27, 31, 38] |  |  |
| Uncertainty in the elicited variables should impact the model and/or decision | [15, 16, 27, 35, 36] |  |  |
| Use neutral wording | [16, 27] |  |  |
| Decomposition or disaggregation |
| Decompose variables of interest to aid experts in the elicitation task |  | [16, 18, 32, 33, 38] |  |
| Handling dependence |
| Express dependent variables in terms of independent variables | [19, 38] |  |  |
| Conditional probabilities | [38] | [19] |  |
| Use separate dependence elicitation methods | [15] | [19, 27, 36] |  |

**Table 4A. Encoding judgements: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| General approach |
| Variable interval methods (including quartiles, bisection) | [15, 16, 26, 29, 38] | [13, 18, 19, 32, 36] |
| Fixed interval methods (including the roulette or chips and bins method) |  | [13, 16, 18, 19, 32, 36] |
| Hybrid fixed/variable interval method |  | [13, 36] |
| Summary statistics, including moments or measures of central tendency |  | [13, 19, 32, 35] |
| Ask only for minimum and maximum |  | [26, 32] |
| Other specialised procedures | [21, 28] | [19, 31] |
| Related decisions |
| Use visual aids to support the elicitation |  | [18, 19, 31] |

**Table 4A. Identifying and selecting experts: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Number of experts |
| Multiple: Explicitly recommended | [13, 15, 16, 19, 26, 28, 29, 31, 32, 36, 38, 39] |  |
| Multiple: Implied | [18, 33] |  |
| Roles |
| Facilitator (assessor, analyst, coordinator): prepare and conduct elicitation | [15, 16, 18-20, 26-29, 31-33, 35, 36, 38] |  |
| Expert (technical expert, specialist, subject-matter expert): provide judgments (and/or evidence) | [15, 16, 18-20, 26, 27, 29, 31-33, 35, 36, 38] |  |
| Generalists: provide judgments, advise on design, and/or help with the elicitation | [18, 29, 31, 33] |  |

**Table 6A. Selecting experts: Options discussed in the guidelines**

|  |  |
| --- | --- |
| Component and choices | Discussion |
| Desired characteristics for those providing judgements |
| Normative expertise | [32, 33]3 guidelines specify normative expertise is desired but not a requirement.[16, 35, 36] |
| Substantive expertise | [32, 33] |
| Willingness (interest and availability) to participate | [15, 26, 33, 35] |
| Ability to understand questions | [20] |
| Ability to apply skills | [33] |
| Notability | [32] |
| Identification procedure |
| Recommendations by peers, either formally or informally | [15, 16, 18, 31, 33, 35] |
| Research outputs | [15, 16, 18, 35] |
| Known experience | [15, 16, 26, 27, 35] |
| Request for proposals to seek out experts | [29] |
| Profile matrix to identify types of expertise required | [16] |
| Selection procedure |
| Disclosure of personal and financial interests | [18, 19, 27, 33, 36] |
| Pursue diversity in opinions, specialisation, area, institution, etc. | [15, 18, 20, 29, 31-33, 35] |
| Pursue diversity in age, gender, culture | [20] |
| Formal selection criteria developed and applied | [16, 31, 33, 35] |
| Send potential experts a questionnaire | [16, 36] |
| Review CVs of possible experts and have a committee select accordingly | [15, 16] |
| Match possible experts against profile matrix | [16] |
| Possible selection criteria |
| Reputation | [15, 18, 32] |
| Experience and qualifications | [15, 16, 26, 27, 35] |
| Publication history | [15, 16, 18, 35] |
| Diversity in background | [15, 36] |
| Conflicts of interest | [18, 19, 27, 33, 36] |
| Awards | [15, 16] |
| Balancing different viewpoints and managing group dynamics | [15, 18, 27, 36] |
| Peer assessment (such as GEM) | [16] |
| Convenience | [36] |
| Balance of internal and external experts (e.g., include at least 2 external experts) | [15, 26] |

**Table 7A. Training and preparation: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Pilot the exercise |  |  |
| Pilot exercise | [13, 15, 16, 18, 19, 31-33]Implied:[20]  |  |
| Training and preparation for experts |  |  |
| Probability, including subjective probability, and related concepts | [15, 16, 19, 29, 31, 33, 35, 36, 38] | [18, 26, 28] |
| Motivation for elicitation | [13, 15, 16, 20, 29, 32, 38]  | [18, 26] |
| Description of what is required from experts | [15, 20, 32, 33] | [18] |
| How results will be used | [15, 33, 38] |  |
| Elicitation questions | [38] | [15, 31] |
| Example and practice questions | [29, 31-33, 36] | [18, 20] |
| Review of potential biases | [13, 16, 29, 32, 33, 35, 36] | [18, 31] |
| Relevant background information, data, and sources | [18, 26, 27, 33, 35, 36][20] \* | [13, 15, 31] |
| Review assumptions and definitions used in the elicitation | [15, 33] | [26] |
| Description of performance assessment (if relevant) | [15] |  |
| Introduction to dependence (if relevant) | [15] |  |
| Training for other roles |  |  |
| Training for other roles | [32] | Training not discussed, but sample material provided for future facilitators[15, 16, 20, 36] |

\* The IDEA protocol recommends providing background information between rounds, rather than prior to the initial elicitation [20].

**Table 8A. Mode and level of elicitation: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Mode of administration |  |  |
| Face-to-face | [15, 18, 28, 31, 33, 35, 36, 38]Implied:[29] | [13, 20, 26, 27, 32] |
| Remote | [16] | [13, 18, 20, 26, 27, 31, 32, 38] |
| Level of elicitation |  |  |
| Individual | [15, 16, 20, 29, 33]Implied:[26] | [18, 19, 27, 31, 32, 38] |
| Group | [28] | [18, 19, 27, 31, 32, 38] |
| Combination (individual assessment followed by group discussion and assessment) | [35, 36] | [38] |

**Table 9A. Feedback and revision: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Type of feedback |  |  |
| Graphical feedback | [13]\*[20, 28, 29, 36] | [16, 33, 38] |
| Fitted distributions | [29, 36] | [38] |
| Written description of the expert’s rationale |  | [16] |
| Rationales from other experts |  | [16] |
| Data collected in the future | [38] |  |
| Discussion of elicited values | [13] | [36] |
| The expert’s performance scores | [15] |  |
| Result of using elicited values in the model | [15, 35] |  |
| Decision resulting from the expert judgment | [26] |  |
| Draft elicitation report | [28] | [15] |
| What to feed back |  |  |
| The individual’s judgments | [15, 18, 20, 35, 36] | [16] |
| Aggregated group judgments | [20, 26] | [16, 36] |
| Judgments from other individual experts | [20, 35, 36] | [16] |
| Opportunity for revision |  |  |
| Iterate elicitation/feedback rounds | [16, 20, 36] | [26] |
| Update judgements during or immediately after a session when receiving feedback | [13, 18, 28, 29, 31, 33, 38] |  |
| Update judgements after future data is collected | [38] |  |
| Update judgements after circulating draft elicitation report | [28] |  |

\* Choy et al. recommend providing feedback in multiple formats, including visual, listening, discussion, and other options as appropriate. [13]

**Table 10A. Interaction and rationales: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Opportunity for interaction |  |  |
| No interaction |  | [18, 19, 27, 29, 31, 32, 38] |
| Group discussion prior to individual elicitation | [33, 35] | [18, 29] |
| Group discussion and group elicitations | [28, 36] | [18, 19], [32], [35] |
| Group discussion following individual elicitation (with opportunity for revision) | [33, 35] | [18-20, 29] |
| Remote, anonymised interaction | [16] | [18-20, 32] |
| Rationales |  |  |
| Collect/record rationales from experts (about how they made their judgements) | [13, 19, 28, 29, 31, 33, 38]Not explicitly discussed, but implied:[15, 16, 18, 20, 26, 27, 35, 36] | [32] |
| Collect/record rationales from decision makers (about how they used the expert judgements) | [26] |  |

**Table 11A. Aggregation: Recommendations and choices from the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommendation | Choice |
| Aggregation |  |  |
| Aggregate | [15, 16, 19, 20, 28, 29, 35, 36, 38]Implied:[26, 32] | [13, 18, 27, 31, 33] |
| Don’t aggregate |  | [13, 18, 27, 31, 33] |
| Aggregation approach |  |  |
| Mathematical | [15, 16, 20, 33]  | [13, 18, 19, 29, 31-33, 38] |
| Opinion pool |  | [18, 19, 31] |
| Equal weighting | [16, 20, 33] | [15, 18, 29, 31, 32] |
| Performance weighting |  | [15, 18, 31] |
| Analyst-chosen weights |  | [32] |
| Bayesian |  | [18, 19, 32] |
| Behavioural | [28, 36] | [18, 19, 29, 31-33, 38] |
| Combination |  | [31, 33] |
| Other | [28, 35] |  |

**Table 12A. Fit to distribution: Recommendations and choices from the guidelines**

|  |  |  |  |
| --- | --- | --- | --- |
| Component and choices | Recommendation | Choice | Recommended against |
| Fit |  |  |  |
| Fit to parametric distribution | [38] | [16, 19, 27, 29, 32, 36] |  |
| Use non-parametric approaches |  | [19, 29, 32] |  |
| Don’t fit at all |  | [19, 20] |  |
| Distribution |  |  |  |
| Uniform |  |  | [19] |
| Triangular |  |  | [19] |
| Uniform over elicited intervals |  | [19] |  |
| Normal/beta/other parametric distribution |  | [16, 36] |  |
| Fitting method |  |  |  |
| Minimum least squares | [36] | [16, 20, 27] |  |
| Method of moments |  | [27] |  |
| Other |  | [15] (Probabilistic inversion) |  |

**Table 13A. Post-elicitation: Recommendations and choices from the guidelines**

|  |  |  |  |
| --- | --- | --- | --- |
| Component and choices | Recommendation | Choice | Recommended against |
| Feedback from experts on the process |  |  |  |
| Get feedback on the procedure if future data collection contradicts elicitation results | [38] |  |  |
| Ask experts to appraise the elicitation exercise after completing it | [16] |  |  |
| Adjusting judgements |  |  |  |
| Calibrate (i.e., adjust) assessments |  |  | [19, 32] |
| Adjust assessments to improve coherence |  | [19] |  |
| Other small adjustments allowed, if fed back to the experts |  | [16] |  |
| Drop experts from the panel |  | [35, 38] |  |
| Documentation\* |  |  |  |
| Elicitation questions | [19] |  |  |
| Responses from individual experts (if elicited) | [19, 20, 33, 35, 36] |  |  |
| Description of process and assumptions for fitting a distribution | [19, 20, 36] |  |  |
| Discussion of elicitation procedure (and justification for choices made) | [13, 16, 18, 20, 29, 31, 33, 35, 38] |  |  |
| Rationales | [26, 28] | [32] |  |
| Evidence related to elicited quantities | [28] |  |  |
| Aggregated judgements and/or consensus curves | [16, 20, 26, 28, 29, 31, 32, 35, 36, 38] |  |  |
| Discussion of the use/impact of elicitation results | [26-28, 31] |  |  |
| Recording of session(s) | [29] | [18] |  |
| List of experts | [26, 36] | [31] |  |
| Definitions and assumptions | [33] |  |  |
| The process for updating judgments | [26, 27] |  |  |

\* Note: Cooke (2000) [15] recommends documentation but says the specific requirements are case-specific, so it offers no further guidance.

**Table 14A. Managing heuristics and biases: Options discussed in the guidelines**

|  |  |
| --- | --- |
| Component and choices | Discussion |
| Biases relevant for SEE |  |
| Cognitive biases |  |
| Overconfidence | [18-20, 27, 29, 31, 32, 35, 36] |
| Representativeness | [13, 18, 19, 31] |
| Availability | [18, 19, 27, 29, 31, 32] |
| Anchoring and adjustment | [13, 18-20, 26, 29, 31, 32, 36, 38] |
| Conservatism | [19] |
| “law of small numbers” | [19, 27] |
| Hindsight bias | [19, 31] |
| Discrepancy between expert’s beliefs and responses (conscious or unconscious) | [13] |
| Location errors | [13, 35] |
| Tacit assumptions | [13] |
| Inconsistency | [32] |
| Motivational biases | [13, 18, 31-33, 35, 38] |
| Management bias (thinking about goal setting rather than the current system) | [38] |
| Expert bias (being more confident because you are called an “expert”) | [38] |
| Social pressure | [32] |
| Group think and polarisation | [20, 26, 27, 32, 36] |
| Impression management | [32] |
| Wishful thinking | [32] |
| Misinterpretation | [32] |
| Misrepresentation | [32] |
| Bias elimination or reduction strategies |  |
| Give experts practice and feedback  | [13, 19] |
| Identify biases through discussion with experts | [38] |
| Provide training on biases | [13, 20] |
| Frame questions to minimize biases and ambiguity | [38][20][27][16][13] |
| Provide relevant background evidence | [13, 33] |
| Ask for upper/lower bounds first | [20][33][36] |
| Ask experts to specify the credible interval they have provided | [20] |
| Minimize and record conflicts of interest among the experts | [33] |
| Require the experts address conflicting information | [33] |
| Collect rationales from experts | [33][31] |
| Report anonymous results | [16, 31] |
| Anticipate likely biases | [32] |
| Ask experts about evidence, not the probability | [28] |
| Avoid numbers in questions | [16] |

**Table 15A. Considering the validity of the process and results: Options discussed in the guidelines**

|  |  |  |
| --- | --- | --- |
| Component and choices | Recommended | Choice |
| Characteristics of validity and supporting actions |  |  |
| Faithfully capturing experts’ beliefs* Provide feedback\*
* Calibration could be a pragmatic proxy
* Test that the question is understood
 |  | [19] |
| Fitness for purpose: Does the imprecision in the elicitation process matter in a given context (e.g., by changing the expected utility of a decision)? |  | [19] |
| Calibration * Ask questions with realizations (i.e., seed questions) that allow calibration to be tested
 |  | [19, 31, 38] |
| Calibration and informativeness scoring on seed questions (i.e., the Classical Model)* Score experts according to calibration and informativeness
* Use scores as basis for performance-based weights (related to Aggregation choices)
* Score both individual experts and combinations of experts
 | [15] | [20] |
| Coherence* Ask for sets of probabilities that allow coherence to be tested
* Overfitting (asking for one more summary than is needed)
* Ask for rationales from experts
 | [27] | [19, 38] |
| Consistency* Ask for rationales from experts (and check for inconsistencies)
* Provide feedback
* Derive/give feedback on density function during elicitation
* Multiply/integrate decompositions during elicitation
* Use different elicitation methods and compare results
 | [27, 29, 38] | [13, 19, 31] |
| Internal peer review of process and/or results | [26] |  |
| External peer review of process and/or results | [18, 26, 35] |  |

\* Discussed

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