EKLIPSE

Knowledge & Learning Mechanism
on Biodiversity & Ecosystem Services

Knowledge synthesis for environmental decisions: an evaluation of existing methods, and guidance for their selection, use and development

A report of the EKLIPSE project

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[1] This report is based on EKLIPSE Project Deliverable 3.1. Report and visualisation of strengths and weaknesses of existing approaches and methodologies to jointly provide evidence, identification of potential gaps in existing approaches, and how to address these gaps

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Knowledge synthesis for environmental decisions: an evaluation of existing methods, and guidance for their selection, use and development

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1. Introduction

'Knowledge synthesis' refers to a set of methods used to review, collate and communicate the best available knowledge on a specific topic or question, including explicit scientific knowledge, but also indigenous and local knowledge, or tacit technical or opinion-based knowledge held by stakeholders. The process of knowledge synthesis is a crucial element of any science-policy interface.

Knowledge synthesis is a rapidly developing research field in both the environmental and health sciences, in response to long-term drivers for evidence-based policy. A wide range of knowledge synthesis methods (KSM) have been identified, discussed, tested and are frequently used to inform policy. For some of the methods, particularly systematic reviews and meta-analyses, clear methodological guidance and training are widely available (see, for example, Collaboration for Environmental Evidence, 2013; Koricheva *et al.*, 2013).

There has been some recent effort in the environmental science literature to provide an overview of different KSMs, what types of questions they are useful for and how they articulate together (Dicks *et al.*, 2014; Pullin *et al.,* 2016). However, at present there is no resource that brings together methodological guidance with an assessment of the features, strengths and weaknesses of the different methods in widespread use.

The goal of the EKLIPSE project is to bring scientists, policy-makers and others together, to ensure that decisions that affect the environment are made with the best available knowledge. Part of this activity relies on selecting an appropriate and feasible KSM or set of KSMs for each specific request or decision. The EKLIPSE project formed an Expert Working Group on Knowledge Synthesis Methods to compile guidance on available KSMs, and develop a process for selecting among them. This report is the first output from the Expert Group on Knowledge Synthesis Methods.

2. Approach

2.1 The EKLIPSE Expert Group on Knowledge Synthesis Methods

An expert group has been formed, using a formal call through the EKLIPSE Network of Networks. Members of the group (Box 1) were selected by the EKLIPSE Knowledge Coordination Body, to represent a balance of European region, expertise and gender.

The task of the Expert Group on Knowledge Synthesis Methods is to provide and share knowledge about the different available methods for knowledge collation, appraisal and synthesis. These methods will be used to identify and characterise robust evidence and knowledge gaps, in response to requests to EKLIPSE from policy makers and societal actors. 'Knowledge' here can refer to scientific knowledge, technical practitioner knowledge and/or indigenous and local knowledge ('ILK').

The group is described here: http://www.eklipse-mechanism.eu/expert_group_on_methods

BOX 1 Members of the EKLIPSE Expert Group on Knowledge Synthesis Methods

Lynn Dicks	- University of East Anglia, UK (Chair, EKLIPSE partner)
Neal Haddaway	- Mistra EviEM, Stockholm Environment Institute, Sweden
Monica Hernández-Morcillo	- Humboldt University of Berlin, Germany
Emiliya Velizarova	- Forest Research Institute - Bulgarian Academy of Sciences, Bulgaria
Luis Santamaria	- Doñana Biological Station, Spanish Research Council (EBD-CSIC)
Brady Mattsson	- University of Natural Resources and Life Sciences, Vienna
Nicola Randall	- Harper Adams University, UK
Pierre Failler	- University of Portsmouth, UK
Johanna Ferretti	- Leibniz Centre for Agricultural Landscape Research (ZALF), Germany
Romina Rodela	- Södertörn University, School of Natural Sciences, Technology and Environmental Studies, Sweden
Heidi Wittmer	- UFZ (KCB, EKLIPSE partner)
Barbara Livoreil	- FRB, France (KCB, EKLIPSE partner)
Heli Saarikoski	- SYKE (EKLIPSE partner)

2.2 Workshop

The Expert Group on Knowledge Synthesis Methods met in Berlin on 12-13th October 2016 to agree on a set of KSMs and outline steps towards delivering the report and visualisation about the strengths and weaknesses of existing approaches and methodologies.

The workshop agenda and list of participants are provided in Appendix I.

2.3 Selection and evaluation of methods

An initial list of available KSMs was drawn up using the literature (Dicks *et al.*, 2014; Pullin *et al.*, 2016), and knowledge within the expert group. During and after the workshop the list was refined to a final list of 21 KSMs.

This should not be considered a final or definitive list of all KSMs. It can be expected to evolve as new methods are developed, and is subject to change as the methods are tested and evaluated during the EKLIPSE project.

For each KSM, the group gathered information on the following features:

- Cost
- Time required
- Repeatability
- Transparency
- Risk of bias
- Scale (or level of detail)
- Capacity for participation
- Data demand
- Types of knowledge that can be synthesized
- Types of output that can be produced
- Specific expertise required

During the workshop, the group identified the main strengths and weaknesses of each KSM.

2.4 Collection of case studies for use of different methods in policy decisions

At the EKLIPSE first joint science-policy-society conference on December 7-8 2016, Brussels, participants were asked to provide examples of the use of the different KSMs for policy decisions. Case study examples were collected and are briefly summarised below.

The Expert Group on KSMs facilitated three group discussions, in which problems-questions were identified by delegates. Different KSMs were then suggested by the participants to gather the existing knowledge to address each of the questions.

3. Outcomes

3.1 Methods identified

Table 1 provides a list of the 21 Knowledge Synthesis Methods (KSMs) identified to develop guidance for EKLIPSE. The categorisations in Table 1 and Figure 1 are used to summarise the more detailed assessment of the 11 features of each method listed in section 2.3. Information for each feature, for each method, is provided in the guidance tables included as Appendix II.

The detailed information for each method (Appendix II) is in draft form. This will be refined over the coming months and used to produce EKLIPSE guidance notes on the KSMs, which will be published on the EKLIPSE website.

For clarity, 'Systematic Review' in this report refers to a formal protocol originally defined by the Cochrane Collaboration[2], now used by the Collaboration for Environmental Evidence[3] and the Campbell

[2] www.cochrane.org
[3] www.environmentalevidence.org

Collaboration[4]. The term is often loosely used to refer to a literature review that has been done somewhat systematically. This is not what is meant here.

3.2 Summary and visualisation of method strengths and weaknesses

The key strengths and weaknesses of each method identified by the group are given in Appendix II. There are many different ways to present these strengths and weaknesses.

Figure 1, shows how the methods can be categorised according to broad categories of: Time/resources required, Capacity for participation and Risk of bias. These three factors were chosen because they were most frequently referred to among the lists of strengths and weaknesses across all the methods. They are likely to be important to policy makers in selecting a KSM for a particular knowledge synthesis request.

For 'Time/resources required', a general guide is that methods which can be completed in less than one month (4 weeks) are in the 'low category'. If 1-6 months are likely to be needed, the category is medium, and 'high' time/resource requirement is loosely defined as more than 6 months. These boundaries are necessarily fuzzy, and must be considered only as a very rough guide. Where the time/resource estimate is based on staff time (weeks or months of Full Time Equivalent, FTE), it can obviously be condensed by using more than one staff member. For many of the KSMs, the actual time and resources required are highly variable, and depend on the complexity and scale of the issue. For example, although Rapid Evidence Assessment and Scoping Review are both classed as 'medium' for time/resources, Rapid Evidence Assessments almost always take more time, and can overlap with Systematic Reviews (categories as 'high' for time/resources) in the amount of resource required, depending on the complexity of the issue.

Readers are encouraged to refer to the notes for each KSM in Appendix II to discover whether the expert group felt it was possible to define clear boundaries for time/resources for each method.

For 'Capacity for participation' and 'Risk of bias', the KSMs are categorised subjectively relative to one another. It is difficult to provide a clear definition that works across all methods for where the boundaries lie between different levels of these factors.

The colour scheme in Figure 1 speculates that low resource cost, high participation and low risk of bias are usually the aims for knowledge synthesis methods. However, this may not always be true. For example, where knowledge synthesis is needed for a large and important policy area that recurs regularly (such as the Common Agricultural Policy, for example), or where the stakes are very high in terms of human well-being (such as climate change adaptation or disease risk), a knowledge requester may not be aiming for a low cost solution.

The balance among these and other features of knowledge synthesis methods will be unique for each request.

Figure 2 presents the same information a different way, to illustrate potential trade-offs between pairs of the three factors. For example, Figure 2a shows that in general the KSMs with low risk of bias are costly in terms of time and resource. The exception to this is Meta-Analysis (MA), which can be done relatively quickly, but only if the data are already compiled. However, Meta-Analysis is not usually useful as a stand-alone KSM, because it relies on a pre-existing review. The real costs are dependent on the method of

[4] www.campbellcollaboration.org

review that was used, which could be a Systematic Review (high), or a Rapid Evidence Assessment (medium cost, but introducing a medium risk of bias).

Figure 2b shows that many KSMs can involve medium or high degrees of participation. Among these, there is a wide range in the risk of bias. In this categorisation, only Collaborative Adaptive Management has a high capacity for participation and low risk of bias.

Viewed together, Figure 2 illustrates that none of the KSMs in our list combine the characteristics of low resource cost, high participation and low risk of bias.

Table 1: 21 Knowledge Synthesis Methods

Showing the code used to identify each method in Figures 1-3, and a simple categorisation of resource requirement, capacity for participation and risk of bias, used to develop visualisation of strengths and weaknesses. More information about each method, including references for open access guidance and an evaluation of strengths and weaknesses, are included in Appendix II. Possible fuzzy boundaries for Time/resource requirement: High = likely to require 6 months or more; Medium = 1-6 months; Low = less than one month (see text for further explanation of categories).

Method	Code	Time and resource requirement	Capacity for participation	Risk of bias
Systematic Review	SystR	High	Medium	Low
Solutions Scanning	SolS	Low	High	Medium
Summaries and Synopses	Sum	High	Medium	Low
Meta-Analysis[5]	MA	Low	Low	Low
Rapid Evidence Assessment	REA	Medium	Medium	Medium
Scoping Review	ScopR	Medium	Medium	Medium
Systematic Map	SM	High	Medium	Low
Vote-Counting	VC	Low	Low	High
Non-Systematic Literature Review	NSystR	Medium	Low	High
Expert Consultation	ExC	Low	Medium	High
Multiple Expert Consultation with Formal Consensus Method such as Delphi	ECwD	Low	Medium	Medium
Causal Criteria Analysis[6]	CCA	Low	Medium	Medium
Bayesian Belief Networks[6]	BBN	Medium	Medium	Medium
Focus Groups	FG	Low	Medium	High
Discourse Analysis	DA	Medium	Low	Medium
Joint Fact Finding (JFF)	JFF	Medium	Medium	High
Scenario Analysis	Scen	Low	High	Medium
Structured Decision Making	SDM	Medium	High	Medium
Collaborative Adaptive Management[6]	CAM	High	High	Low
Participatory Mapping	PM	Medium	High	Medium
Multi Criteria Decision Analysis	MCDA	Medium	High	Medium

[5] Meta-analysis is not a standalone method, but relies on a pre-existing review, with its accompanying costs and risk of bias.

[6] These three methods usually employ other KSMs, such as forms of review and expert consultation, as integral to the process.

Figure 1. How the 21 KSMs fall among the categories

Figure 1 shows how the 21 KSMs fall among the categories High, Medium and Low on the three broad factors identified as strength or weakness, as described in Table 1. Codes are given in Table 1. The colour scheme is used to anticipate which end of each scale might be considered more desirable, where green = desirable (low cost, high participation, low risk of bias) and red = undesirable. This scheme is speculative, and will differ among policy contexts.

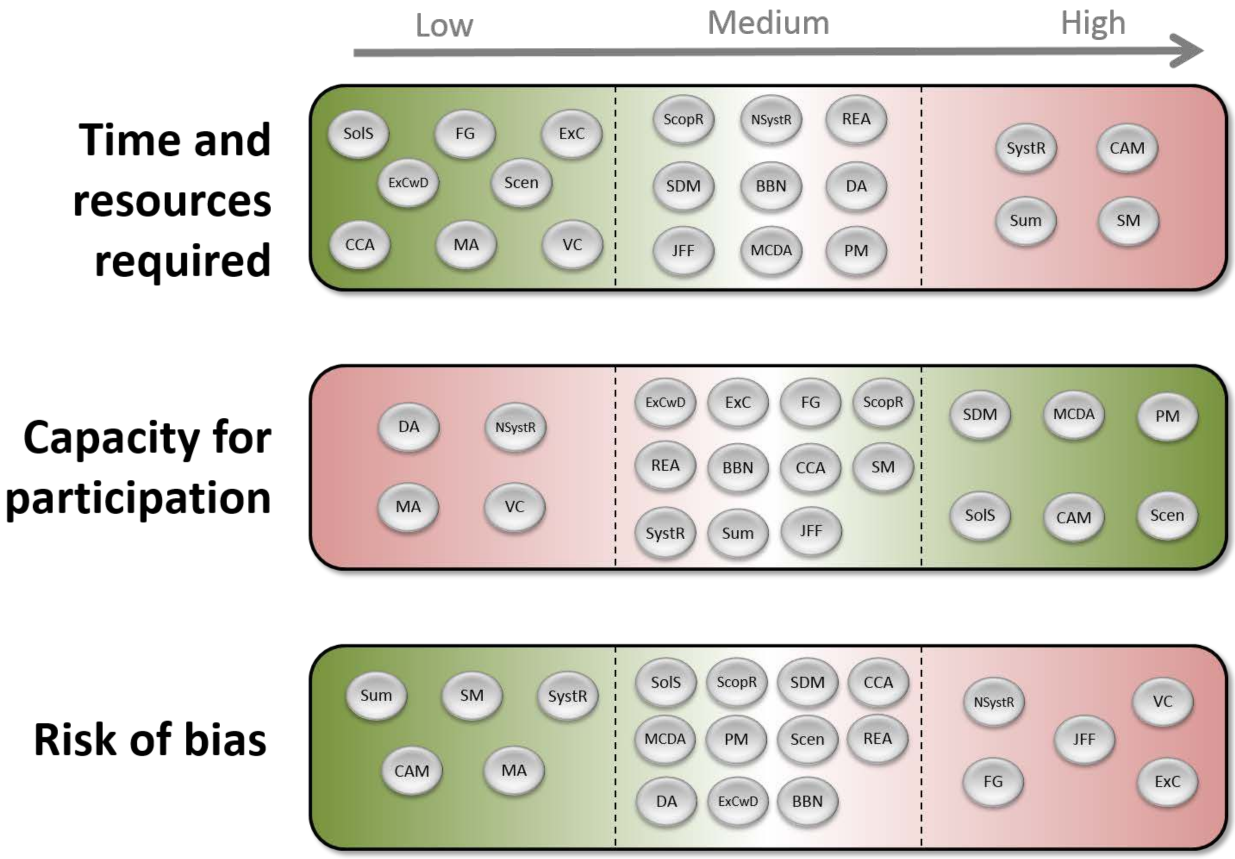
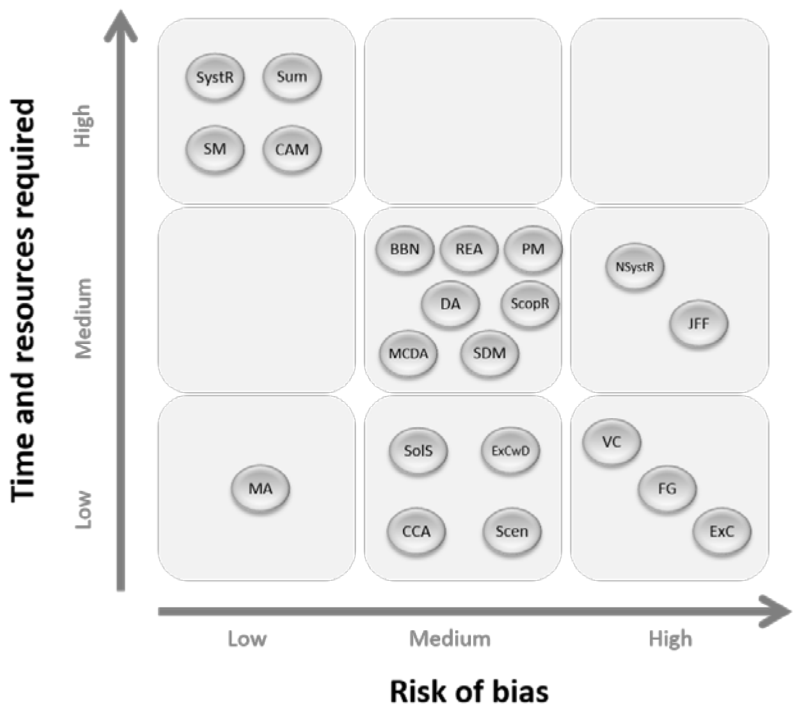
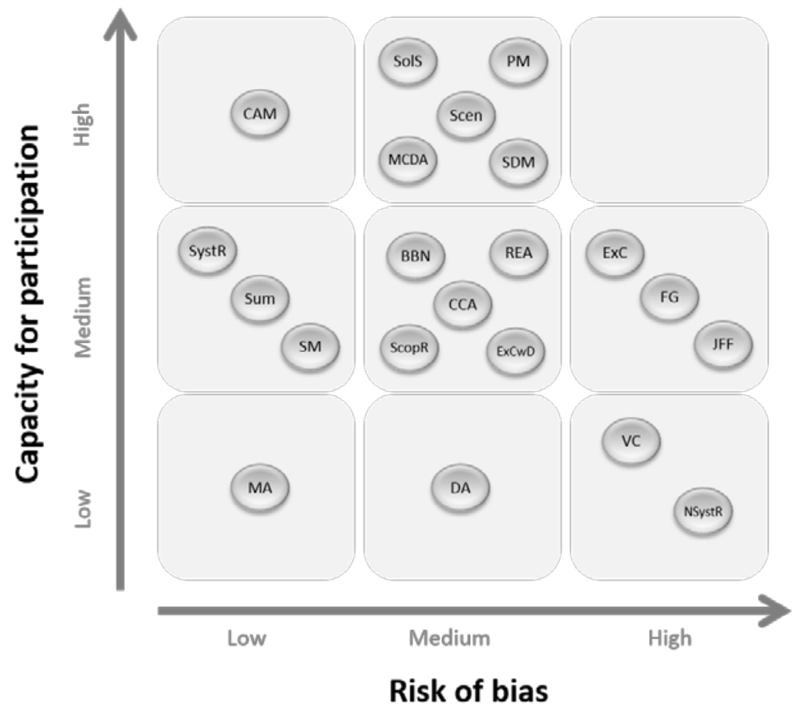


Figure 2. The distribution of the 21 KSMs

The distribution of the 21 KSMs when two strength/weakness factors are seen simultaneously, to illustrate trade-offs: a) Time/resource against risk of bias; b) Capacity for participation against risk of bias. Codes for individual methods are given in Table 1.





3.3 Articulating or combining methods for application during policy cycles

Discussions with policy makers and other stakeholders at the EKLIPSE Science-Policy-Society conference (see 2.4) led to the following general observations.

No single KSM can be used to completely answer a policy question. However, a logical combination of methods can be identified to answer most policy questions. These combinations usually involve a method from one of each of four general groups: exploratory methods, engagement methods, analytical methods and evaluation methods. These groups can be related to different phases in the policy cycle where they are most likely to be useful.

Exploratory methods review and collate evidence in a more or less intense way depending on time and resources availability. Relevant policy cycle phase: agenda-setting.

Engagement methods collect stakeholder opinions and the expert contributions through focus groups, expert consultations or Delphi processes. This group of methods can potentially be applied throughout the policy cycle, including implementation and evaluation, but they are more often indicated for the earlier phases in the cycle. Relevant policy cycle phases: all.

Analytical methods use KSM to analyse and compare possible courses of action, for example through scenario building, collaborative adaptive management or multi-criteria analysis. Relevant policy cycle phase: policy formulation.

Evaluation methods. For analysing policy impacts, the set of methodologies with predictive power, such as scenario building, are useful. To systematically evaluate policy structures, acceptance and narratives the most indicated KSM were: structured decision making, joint fact finding and discourse analysis. Relevant policy cycle phase: policy evaluation.

Table 2 lists the KSMs that could fit into each of the four groups. Some methods can be allocated to more than one group. For example, participatory mapping can be used to collate and review existing local or regional knowledge about an ecosystem, but also as an engagement tool to collect attitudes and opinions, or as an evaluation tool to validate maps generated by other processes.

Some methods are inter-dependent, and rely on other methods to provide useful knowledge synthesis. For example, Causal Criteria Analysis (CCA), Bayesian Belief Networks (BBN) and Collaborative Adaptive Management (CAM) all employ other KSMs to synthesize evidence for specific links in the causal chain. In the case of CCA, Systematic Review (SystR) is recommended (Norris *et al.*, 2012), although if less resource is available, similar less rigorous results could be achieved using Rapid Evidence Assessment (REA) or Multiple Expert Consultation + Delphi (ExCwD).

Table 2. The EKLIPSE Knowledge Synthesis Methods

The EKLIPSE Knowledge Synthesis Methods as they apply to different general purposes in relation to the policy cycle. See text for explanations of column headings.

Method	Explore	Engage	Analyse	Evaluate
Systematic Review	✓		✓	✓
Solutions Scanning	✓			
Summaries and Synopses	✓			
Meta-Analysis	✓		✓	
Rapid Evidence Assessment	✓		✓	✓
Scoping Review	✓			
Systematic Map	✓		✓	✓
Vote-Counting	✓			
Non-Systematic Literature Review	✓		✓	✓
Expert Consultation		✓		✓
Multiple Expert Consultation with Formal Consensus Method such as Delphi	✓	✓	✓	✓
Causal Criteria Analysis	✓	✓		
Bayesian Belief Networks	✓	✓	✓	
Focus Groups		✓		✓
Discourse Analysis				✓
Joint Fact Finding (JFF)		✓		✓
Scenario Analysis	✓	✓	✓	✓
Structured Decision Making			✓	✓
Collaborative Adaptive Management	✓	✓	✓	✓
Participatory Mapping	✓	✓		✓
Multi Criteria Decision Analysis			✓	

Within each of the groups in Table 2, there are sets of methods that serve a similar purpose but offer increasingly rigorous, unbiased (and usually costly) knowledge synthesis. For example, Rapid Evidence Assessment and Quick Scoping Reviews are condensed versions of Systematic Review and Systematic Map, respectively. Each misses out elements of the full method to reduce time and costs, for example by applying arbitrary limitations to searches such as limiting the number of resources searched or publication date range (subsampling), or by simplifying screening and critical appraisal activities. This is the reason why their results may be more subject to bias.

Similarly, within engagement methods, Focus Groups and Expert Consultations are low cost, rapid methods. If more resources are available, more complete and less biased synthesis of knowledge can be achieved using Multiple Expert Consultation + Delphi or by constructing a Bayesian Belief Network or Causal Criteria Analysis.

KSMs can be combined in many different combinations to serve a specific purpose, and combining KSMs of different types (as in Table 2) offers the opportunity to cover broader or areas of the policy cycle (Figure 3). For example, Multiple Expert Consultation + Delphi (ExCwD) can be combined with Summaries and Synopses (Sum), or a Systematic Map (SM), to analyse evidence over a broad area relatively quickly. This combined approach has been demonstrated for effectiveness of actions to enhance ecosystem services on farms (Dicks *et al.*, 2016; Key *et al.*, 2016).

QUICKScan is another example of how different KSMs can be combined. QUICKScan (Verweij *et al.*, 2016; Dick *et al*., 2017) is a decision support system that uses spatial data, and is meant to be used in a group setting to produce synthetic summaries of different types of knowledge. Its delivery is informed by a participatory methodology, and so it combines procedures used in focus groups, expert consultation, scenario analysis and participatory mapping.

Finally, to combine and synthesize knowledge that arises from different knowledge systems, different appropriate KSMs can be brought together to form a 'Multiple Evidence Base' from which "different knowledge systems are viewed as generating equally valid evidence for interpreting change, trajectories, and causal relationships." (Tengö *et al*., 2014).

Figure 3. How the different groups of KSMs apply to stages of the policy cycle

The Knowledge Synthesis Methods in each group are shown in Table 2. The policy cycle itself is shown in blue. Central policy cycle figure adapted from (IPBES, 2016).

3.4 Developing an EKLIPSE process for selecting appropriate methods

The Expert Group on Knowledge Synthesis Methods developed a set of questions to help select an appropriate Knowledge Synthesis Method for specific EKLIPSE requests, during a dialogue with the requester. The questions, and for some the available options, are provided in Appendix III.

At the time of writing, this is an ongoing workstream for the Expert Group on KSM. The questions are currently being tested in the EKLIPSE requests for 2017, to assess how well they are able to identify an appropriate KSM or set of KSMs. The process will be evaluated during formal evaluation of EKLIPSE (Work Package 2).

Members of the group, led by Brady Mattsson, are developing a Bayesian Belief Network that estimates the probability of each KSM being useful given a particular set of conditions, based on expert judgements and using a subset of these questions. If successful, this BBN approach will add substantial rigour to the EKLIPSE process for selecting Knowledge Synthesis Methods.

3.5 Case studies of method use

We present two hypothetical examples identified and discussed at the EKLIPSE science-policy-society conference.

Example 1

Requester: Environmental office of a bank. They want to invest money in environmental projects and need a way to select projects.

Question: How can we distribute loans to invest on improving nature? Which are the environmental problems that can be solved by our targeted investments?

Time frame: 2 months

Knowledge Synthesis Methods proposal:

1. A Scoping Review to explore the evidence used in other similar initiatives and the biological evidence on environmental problems in the area.
2. Expert Consultations with bankers and other sectors to identify what they really want to achieve.
3. Focus Groups with local stakeholders and policy makers on what are the environmental problems.

Example 2:

Requester: Environmental Agency in Austria.

Question: What is the impact of agriculture expenditure from CAP in Biodiversity?

Knowledge Synthesis Methods proposal:

1. Expert consultation to define a relevant question.
2. Systematic reviews of evidence to collect the existing information and draw the base lines.
3. Expert consultation to build the biological evidence.
4. Focus groups: to assess why the farmers choose one or another land management decision.
5. Structured decision-making (SDM): to assess the win-win solutions (good for agriculture and biodiversity) and to assess the barriers that farmers have to adopt the win-win actions.
6. Scenarios: would be interesting for policy proposals.

4. Synthesis and conclusions

We have identified and characterised 21 Knowledge Synthesis Methods. The EKLIPSE project will publish clear guidance on each method, including links to resources that explain how to carry out the method.

This is unlikely to be a definitive or unchanging list. Knowledge Synthesis Methods are developing all the time, and there are inter-dependencies among them (see section 3.3). For example, application of the systematic mapping method to environmental questions is relatively new, but its use has grown very rapidly. The first environmental systematic map was published in 2012 (Randall and James, 2012), and the method only recently described in the environmental literature (Dicks *et al*., 2014; James *et al*., 2016).

To our knowledge, this is the first time guidance on such as broad set of KSMs has been brought together. The EKLIPSE project will monitor the usefulness of both the guidance documents and the decision support questions, during science-policy-society interactions, through its formal evaluation.

In general, many responses to policy questions are currently provided by consultancy firms working on tendered contracts, rather than by publicly funded scientists. An example is an evaluation of the Common Agricultural Policy (Poláková *et al*., 2011). Such reports tend to use of a narrow set of Knowledge Synthesis Methods. Those defined here as Non-Systematic Literature Review and Expert Consultation (through stakeholder interviews) are usually employed together to provide analysis and recommendations.

We hope that the guidance and clarity provided by the EKLIPSE project will help policymakers and science-policy interface mechanisms to move towards using more rigorous KSMs with lower risk of bias. We also expect this work to increase transparency, by enabling clearer definitions of methods that have been used to inform policy.

4.1 Where are the gaps?

4.1.1 Rapid scoping and review

At present there is not a well-defined method available that can use elements of the rigorous systematic approaches to gain an unbiased view of the documented scientific literature on a new topic, in the short time scales often required for policy questions (one month or less, the 'low' time/resource category in Figure 2). The shortest well-defined methods, here called 'Scoping Review' and 'Rapid Evidence Assessment' take two months or more, when carried out according to the best available guidelines (Collins *et al*., 2014), as both require a carefully set out and tested search protocol. As a result of this, policymakers often use non-systematic literature review, vote counting, or expert judgement for evidence reviews as part of assessing policy impacts.

One response to this gap is to encourage the use of horizon scanning, or planning processes, so that policy questions requiring evidence are foreseen with longer timescales. For example, there is a current urgent need to provide evidence about the environmental impacts of the Common Agricultural Policy (CAP). This very large policy is regularly reviewed and reformed, on timescales that are highly predictable. For policy questions that do not recur, horizon scanning can help to anticipate policy questions in advance (Sutherland *et al*., 2017).

It may be that there is no chance of consulting the scientific literature in the timeframe of less than a month, and this should simply be accepted as a boundary by science-policy-interfaces. On the other hand, there may be scope for an extremely shortened method to be defined, although its shortcomings would have to be made very clear.

4.1.2 Large-scale review and assessment

There are several on-going scientific assessments at international and global scale in the area of biodiversity and ecosystem services, such as those organised by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC). These processes involve tens or even hundreds of scientists, who collectively write assessment reports. The authors are mostly nominated by Governments and selected to be representative of disciplines, global regions and gender.

The assessments represent a massive knowledge synthesis process, and they are expected to represent an unbiased, rigorous and comprehensive overview of existing knowledge. In the case of IPBES, there is a clear mandate for the assessment reports also to synthesise Indigenous and Local Knowledge (ILK), as well as scientific and technical knowledge (Sutherland *et al*., 2014). But the assessments published so far (for example, IPBES, 2016) do not follow methods of knowledge synthesis defined here as having high transparency and low risk of bias. They do not follow formal systematic map or systematic review methods as described here (Appendix II). Some chapters are aiming towards Scoping Review or Rapid Evidence Assessment, but without consistent reporting of methods, they can only really be defined as Non-Systematic Literature Review. This is unsatisfactory, given the position of this method (NSystR) in Figures 1 and 2.

These international assessment processes aim to reduce bias by involving a broad set of scientists and incorporating very intensive and widespread peer review, with hundreds of reviewers. The extent to which this is able to reduce bias, as opposed to introducing further bias, is entirely unclear and requires research.

Acronyms used

FTE Full time equivalent (with reference to time, in measuring staff resources)

KSM Knowledge Synthesis Methods

ILK Indigenous and Local Knowledge

Glossary

Term	Definition
Knowledge synthesis	Review, collation and communication of the best available knowledge on a specific topic or question, including explicit scientific knowledge, but also indigenous and local knowledge (ILK) and tacit, technical or opinion-based knowledge held by stakeholders.
Tacit knowledge	Knowledge that requires input from the person who generated knowledge to document or aggregate it.
Explicit knowledge	Knowledge that can be documented or aggregated without input from person who generated the knowledge.
Scientific knowledge	Knowledge gathered using scientific processes of hypothesis testing and data gathering.
Technical knowledge	Knowledge held by individuals or institutions, developed through past experience and expert judgement. Sometimes called experiential or anecdotal knowledge.
Opinion-based knowledge	Knowledge held by individuals, based on a combination of other forms of knowledge, but also informed by values (preferences relating to priorities for action or particular outcomes) and mental models (the cognitive frameworks that people use to interpret and understand the world).
Indigenous and local knowledge (ILK)	A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. It is also referred to by other terms such as, for example, Indigenous, local or traditional knowledge, traditional ecological/environmental knowledge (TEK), farmers' or fishers' knowledge, ethnoscience, indigenous science, folk science (Díaz *et al*., 2015).

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Verweij, P. *et al*. (2016). *QUICKScan as a quick and participatory methodology for problem identification and scoping in policy processes.* Environmental Science & Policy 66: 47-61.

Appendix I: Agenda and participant list for the Expert Group on KSM workshop

The workshop was held at the Helmholtz Association, Berlin Office, Anna-Louisa-Karsch-Straße 2, 10178 Berlin, 12-13 October 2016.

Participants:

- Lynn Dicks - University of East Anglia, UK
- Heidi Wittme - UFZ, Germany
- Barbara Livoreil - FRB, France
- Heli Saarikoski - SYKE, Finland
- Juliette Young - Centre for Ecology & Hydrology, UK
- Neal Haddaway - Mistra EviEM, Stockholm Environment Institute, Sweden
- Monica Hernández-Morcillo - Humboldt University of Berlin, Germany
- Emiliya Velizarova - Forest Research Institute - Bulgarian Academy of sciences
- Brady Mattsson -University of Natural Resources and Life Sciences, Vienna
- Nicola Randall - Harper Adams University, UK
- Johanna Ferretti - Leibniz Centre for Agricultural Landscape Research (ZALF), Germany
- Romina Rodela - Södertörn University, School of Natural Sciences Technology and Environmental Studies – *attended by Skype*

Agenda

Day 1:	**Aim: To decide a list of Knowledge Synthesis Methods (KSMs) and the framework for our guidance**
12:30	*Welcome lunch*
13:00	Setting the scene: Heidi Wittmer: introduction to EKLIPSE, and previous work on knowledge synthesis methods in BiodiversityKnowledge Lynn Dicks: aims and objectives for expert group and workshop (including an account of use by NBS group) Time for questions
13:30	Getting to know each other
14:00	Agree set of Knowledge Synthesis Methods (KSM) and devise working groups for 13th October
14:45	*Coffee*

15:00	Agree on what features of methods to gather information and present guidance on. Preliminary list: • Cost • Time resource • Risk of bias • Level of transparency/repeatability • Type of request (Recurring question? How will it be used?)
16:00	Discuss the structure of guidance for expert groups • What does it look like? • How will it show strengths and weaknesses? Aim to have a draft structure by 17:30

Day 2:	**Aim: To develop guidance content for EKLIPSE expert groups**
9:00	Short plenary followed by small working groups
Working groups	For each KSM, identify the following: • Strengths and weaknesses • Method detail (+ pdfs of key publications describing method) • Examples of application in science-policy interface or discuss potential to adapt to SPI situation. • Information about cost/time resources and specific expertise required with case study?) Each group to document their findings in a pro forma (provided by Lynn)
12:30	*Lunch*
13:30	Plenary • Report back from working groups • Revisit guidance structure developed in Day 1. Does it still work? • Agree visual structure
14:30	*Coffee*
15:00 – 16:00	Discussion: • Gaps in existing methods and how to address them • Allocation of work (how to complete EKLIPSE deliverable by January) • Ways of working: UFZ cloud server etc. • How our approach can add to existing literature (e.g. feedback from policy and practice on KSMs etc.) • Next steps: including interest to take this work further

Appendix II: Guidance notes for each method

This guidance document provides an overview 21 Knowledge Synthesis Methods for use in environment-related Science-Policy-Society Interfaces. **Key references** are open access resources that provide instructions on how to conduct each method, in the context of environmental science and policy whenever this is available. In cases where the best or only available resource is not open access, this is clearly indicated.

1. Systematic review

Summary of method

A structured, step-wise methodology following an *a priori* protocol to comprehensively collate, critically appraise and synthesise existing research evidence (traditional academic and grey literature). This method is applicable to specific questions such as: What is the effectiveness of an intervention? What is the effect of X on Y? What is the prevalence of a phenomenon? How reliable is a specific method?

Systematic review relies on the existence of scientific knowledge and is not usually appropriate for emerging topics or knowledge gaps (although 'empty reviews' may be valuable).

Systematic reviews should be conducted according to the rigorous standards demanded by review coordinating bodies such as the Cochrane Collaboration[7], the Collaboration for Environmental Evidence[8] and the Campbell Collaboration[9] (see references below).

Reporting requirements include: protocol of methods, fates of all articles screened at full text, transparent documenting of all methods used.

The method includes tertiary reviews, or systematic reviews of reviews.

Key references

Collaboration for Environmental Evidence (2013). *Guidelines for Systematic Review and Evidence Synthesis in Environmental Management. Version 4.2.* Environmental Evidence, www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf

Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011].* The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org

[7] www.cochrane.org
[8] www.environmentalevidence.org
[9] www.campbellcollaboration.org

Examples of application

The Global Environment Facility commissioned and funded a systematic review on the impacts of terrestrial protected areas on human wellbeing (Pullin *et al.* 2013). This review was a mixed methods systematic review involving quantitative and qualitative syntheses. In general, the evidence base was found to be particularly poor and many impacts reported by qualitative research were not studied quantitatively.

Pullin, A.S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N.R., Healey, J.R., Hauari, H., Hockley, N., Jones, J.P., Knight, T. and Vigurs, C., (2013). *Human well-being impacts of terrestrial protected areas.* Environmental Evidence, 2(1), p.1.

See Environmental Evidence Journal http://environmentalevidencejournal.biomedcentral.com/ for multiple other examples of systematic reviews. Many examples of these reviews were requested by stakeholders and an advisory board was involved in scoping and designing the review protocol.

Systematic review	
Cost	Staff (6-24 months FTE), subscriptions (database access, article access), software (reference/specialist review management), travel and subsistence, expert (informatician, quantitative/qualitative specialist) Affected by: size of the evidence, existence of previous reviews, need for specialist expertise, complexity of the question, required level of rigour
Time required	6 months - 4 years Affected by: quantity of literature, availability of staff, response time, existence of previous systematic reviews or maps (allowing a systematic review of systematic reviews, or a rapid systematic review following production of a systematic map)
Repeatability	High (if conducted, recorded, and archived properly)
Transparency	High (if conducted well, i.e. endorsed by a systematic review co-ordinating body)
Risk of bias	Low (if conducted well), acknowledges risk of bias transparently in evidence base and review method
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Potential consultation throughout
Data demand	High
Types of knowledge	Scientific/technical, explicit

Types of output	Written report plus other communication materials (e.g. policy brief), list/description/database of existing evidence, answer to question, identification of knowledge gap
Specific expertise required	Systematic reviewer/informatician, topic expert, quantitative/qualitative specialist

Strengths	Weaknesses
Full documentation allows verification and repeatability	High time/resource (staff and expertise/training/access to research papers) requirement
Updating is relatively quick if methods reported well	Report typically written only in English
Protocol externally peer-reviewed and published, increasing transparency and registering intent to conduct the review	Difficult to interpret main report without additional forms of communication (e.g. factsheets), although these are usually done
Comprehensive	Not suitable for broad topic areas
Low risk of bias	
Open access	
Highly resistant to criticism	
Always peer-reviewed	
Coordinating bodies exist that can act as additional endorsement	
Includes stakeholder engagement	
Can be relatively fast if multiple systematic reviews already exist on the topic (systematic review of systematic reviews can be performed)	

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2. Solution scanning

Summary of method

A structured, step-wise methodology to identify a long list of available actions, interventions or approaches, in response to a broad challenge. A list is gathered through consultation with a wide range of stakeholders, and continues to be circulated through networks until five new people have seen it and add nothing.

Solution scanning forms the first step in Summaries of evidence.

Key references

Sutherland WJ, Gardner T, Bogich TL et al (2014). *Solution scanning as a key policy tool: identifying management interventions to help maintain and enhance regulating ecosystem services.* Ecol Soc 19:3. doi:10.5751/ES-06082-190203.

Examples of application in policy

This method was used to identify a long list of possible actions that constitute 'sustainable intensification' of agriculture, during the Sustainable Intensification Platform (http://www.siplatform.org.uk/) funded by the UK Department for Environment Food and Rural Affairs (Defra; Dicks *et al.* in prep). The most promising actions from among the list were prioritised by a group of stakeholders to inform subsequent research activity.

Solution scanning	
Cost	1 month (FTE)
Time required	Can be completed within 1 month, if needed. Maximum 3 months
Repeatability	Low to Moderate. There is no definitive list New possibilities occur over time
Transparency	High (if conducted well)
Risk of bias	Moderate. Contents of the list depend on who is asked to contribute. Conducted properly, a very wide range of stakeholders should be included and the risk of bias reduced
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	High
Data demand	No data required
Types of knowledge	Science/technical/opinion; Tacit
Types of output	Written list of options

Specific expertise required	None. The consultees who build the list should have practical experience in the policy area

Strengths	Weaknesses
Powerful tool at an early stage in the policy cycle Suitable for very broad topic areas	Does not provide any evidence for the effects/impacts of the different solutions

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3. Synopses and summaries

Summary of method

Flexible, transparent approach to collate and summarise existing research evidence over a broad topic in a standard format. Interventions, actions, or impacts are first listed (can use a process of Solution Scanning). Review methods are flexible and pragmatic, selecting and reporting the best available search methodology, with a focus on existing systematic reviews and systematic maps where possible.

Key references

Detailed guidance on how to conduct this method is held by the Conservation Evidence project at the University of Cambridge (www.conservationevidence.com). Sutherland *et al.* (2017) provides a summary of the method.

Sutherland *et al.* (2017) *What Works in Conservation?* OpenBook Publishers. Available from www.conservationevidence.com

Examples of application

This approach was used by Natural England (an English government agency) to help select actions to include in Wild Pollinator and Farm Wildlife package of agri-environment scheme options, in the English Countryside Stewardship Scheme, introduced in 2015 (Dicks *et al.* 2015).

Dicks, L.V., Baude, M., Roberts, S.P.M., Phillips, J., Green, M., C., C. (2015). *How much flower-rich habitat is enough for wild pollinators? Answering a key policy question with incomplete knowledge.* Ecological Entomology 40 (S1), 22-35.

Synopses and summaries	
Cost	Staff (12-120 months FTE), subscriptions (article access), expertise (web platform manager), web design
Time required	12-120 months
Repeatability	High (if conducted, recorded and archived properly)
Transparency	High (if conducted well, i.e. endorsing organisations)
Risk of bias	Moderate-low (due to the methodology, which may not be comprehensive)
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Potential consultation throughout (using an expert advisory board, not public consultation)
Data demand	High (no reanalysis of existing data)

Types of knowledge	Scientific/technical; explicit
Types of output	Interactive website of narrative evidence, user-friendly written report plus other communication materials (e.g. policy brief), identification of knowledge gap/knowledge cluster
Specific expertise required	Training, good writing skills, topic expert, web management specialist

Strengths	Weaknesses
Easy to read/user-friendly	Report typically written only in English
Updatable	High time/resource (staff and expertise/training/access to research papers) requirement
Includes expert engagement	May facilitate vote-counting by end users
Open access	
Appropriate for very broad topic areas	

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4. Meta-analysis

Summary of method

A statistical tool to reanalyse existing data from multiple studies. Meta-analysis is not an independent type of review. It relies on data extracted from an existing set of studies resulting from a review.

Key references

Koricheva, J., Gurevitch, J., Mengersen, K. (2013). *Handbook of meta-analysis in ecology and evolution.* Princeton University Press, Princeton and Oxford.

Examples of application

The following examples have been suggested, but details of a link to actual policy decision-making is not clear.

- Crop responses to conservation agriculture
- Environmental and yield effects of organic farming
- Estimation of adoption and productivity trends
- Understanding forest plots

Meta-analysis	
Cost	Staff: very variable as it will depend on whether data are already available and what type of review is needed to collate data. Can be conducted in three weeks if data are already available. Expert statistician Affected by: size of the evidence
Time required	Can be conducted in three weeks if data are already available
Repeatability	High (if conducted, recorded, and archived properly)
Transparency	High (if conducted and recorded well, i.e. endorsing organisations)
Risk of bias	Low (if conducted well and evidence is reliable). Depends on what has led to the meta-analysis. Bias can be quantified and visualised
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Low
Data demand	High
Types of knowledge	Scientific/technical, explicit

Types of output	Statistical results (usually reported within other type of document)
Specific expertise required	Statistical expert

Strengths	Weaknesses
Powerful statistical tool for summarizing multiple, possibly contradictory research studies	Not a standalone review method, relies upon one of the other synthesis methods to provide data
Allows for assessment of the presence of heterogeneity (disagreement)	Reliability of a meta-analysis depends heavily on the reliability of the data included in the analysis
Extension analyses (including sensitivity analysis, subgroup analysis and meta-regression) allow for the analysis of categorical and continuous explanatory variables that may be causing heterogeneity	Requires considerable technical skill
Publication bias can be assessed statistically	Not suitable for broad topic areas: requires very specific question
Study validity (i.e. quality) can be assessed by weighting studies, for example using critical appraisal results	

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5. Rapid evidence assessment

Summary of method

A structured, step-wise methodology, usually following an *a priori* protocol to comprehensively collate, critically appraise and synthesise existing research evidence (traditional academic and grey literature), following systematic review methodology but with components of the process simplified or omitted to produce information in a short period of time.

The method is sometimes called 'rapid review' (Tricco *et al.* 2015). The exact set of methods used, or the components of systematic review omitted, are flexible, and the method itself is not well defined internationally.

A standardised version of Rapid Evidence Assessment has been defined by the UK Government (Collins *et al.* 2014). This is used for the time and cost estimates below.

Reporting requirements in Collins *et al.* (2014) include: protocol of methods, fates of all articles screened at full text, transparent documentation of all methods used. For more general rapid review, there are no strict reporting requirements, as there are no internationally agreed method guidelines.

Rapid Evidence Assessments, or rapid reviews, are not usually endorsed by a co-ordinating or certifying body. This leads to a wide range in method details, reporting and overall review quality.

Key references

Collins, A., Miller, J., Coughlin, D., Kirk, S., (2014). *The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide.* Joint Water Evidence Group, UK.

Tricco, A.C., Antony, J., Zarin, W., Strifler, L., Ghassemi, M., Ivory, J., Perrier, L., Hutton, B., Moher, D., Straus, S.E. (2015). *A scoping review of rapid review methods.* BMC Medicine 13, 224.

Examples of application

UK Department of Environment, Food and Rural Affairs (Defra) have funded Rapid Evidence Assessments (for example, Waterson and Randall, 2013) for policy questions on water quality.

Waterson A and Randall NP (2013*). What impact does the alteration of timing to slurry applications have on leaching of nitrate, phosphate and bacterial pathogens?* A Rapid Evidence Assessment. http://www.wskep.net/assets/documents/Rapid-Evidence-Assessment-Slurry-application-(280214).pdf

Rapid Evidence Assessment	
Cost[10]	Staff (c.3-6 months FTE), subscriptions (database access, article access), software (reference/specialist review management) travel and subsistence, expert (informatician, quantitative/qualitative specialist) Affected by: size of the evidence, existence of previous reviews, need for specialist expertise, complexity of the question, required level of rigour
Time required	c. 3-9 months Affected by: quantity of literature, availability of staff, response time
Repeatability	Moderate (depends on which components are cut)
Transparency	High (if conducted well, i.e. endorsing organisations), protocol is important
Risk of bias	Medium (depends on which components are cut)
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Potential to participate throughout
Data demand	High
Types of knowledge	Scientific/technical, explicit
Types of output	Written report plus other communication materials (e.g. policy brief), list/description/database of existing evidence, answer to question, identification of knowledge gap
Specific expertise required	Topic expert, quantitative/qualitative specialist(?)

[10] Assumes Collins *et al.* (2014) guidelines followed exactly.

Strengths	Weaknesses
Typically quicker to complete than a gold standard equivalent systematic review	Not fully comprehensive
Follows methodological principles of systematic review	Not as reliable as a full systematic review
Methods are documented transparently and shortcuts are clear to see	Protocol typically not externally peer-reviewed
Often include searches for grey literature	Flexible methods and non-specific guidance means reliability, and risk of bias are variable - many different corners can be cut
Potentially upgradable into a full systematic review without complete repetition	Not usually suitable for very broad topics
	Risk of vote-counting (see Vote-Counting) if results are extracted from studies but not fully synthesized quantitatively

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6. Scoping review

Summary of method

A structured, step-wise methodology, preferably following an *a priori* protocol to collate and describe existing research evidence (traditional academic and grey literature) in a broad topic area, following a systematic map methodology but with components of the process simplified or omitted to produce information in a short period of time.

This is not the same as the scoping stage of a systematic review.

The method has been called 'Quick Scoping Review' (Collins *et al.* 2015). The exact set of methods used, or the components of systematic map that are left out is flexible, and the method itself is not standardised internationally.

A standardised version of Quick Scoping Review has been defined by the UK Government (Collins *et al.* 2014), and this is used for the time and costs estimates below.

Reporting requirements in Collins *et al.* (2014) include: protocol of methods, fates of all articles screened at full text, transparent documenting of all methods used. For more general scoping review, there are no strict reporting requirements, as there are no internationally agreed method guidelines.

Scoping reviews are not usually endorsed by a co-ordinating or certifying body. This leads to a wide range in method details, reporting and overall review quality.

Key references

Collins, A., Miller, J., Coughlin, D., Kirk, S., (2014). *The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide.* Joint Water Evidence Group, UK.

Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., Levac, D., Ng, C., Sharpe, J.P., Wilson, K., Kenny, M., Warren, R., Wilson, C., Stelfox, H.T., Straus, S.E. (2016). *A scoping review on the conduct and reporting of scoping reviews.* BMC Medical Research Methodology 16, 15.

Examples of application

UK Department of Environment Food and Rural Affairs (Defra) has commissioned scoping reviews to inform policy on pesticide regulation (James *et al.* 2014) and to explore the scope for systematic review or summaries to inform policy on sustainable intensification of agriculture (part of this programme: www.siplatform.org.uk; report not currently available).

James K, Randall N and Millington A (2014). *The impact of Pesticides Used in Amenity on Controlled Waters in the UK.* A Quick Scoping Review.

Scoping review	
Cost[11]	Staff (1-6 months FTE), subscriptions (database access, article access), software (reference/specialist review management), travel and subsistence, expert (informatician, visualization/database specialist) Affected by: size of the evidence, existence of previous reviews, need for specialist expertise, complexity of the question, required level of rigour
Time required	1-6 months Affected by: quantity of literature, availability of staff, response time
Repeatability	Moderate
Transparency	High (if conducted well, i.e. endorsing organisations), protocol is important
Risk of bias	Medium (if conducted well). Should acknowledge risk of bias transparently in evidence base and review method
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Potential consultation throughout
Data demand	High
Types of knowledge	Scientific/technical, explicit
Types of output	Written report plus other communication materials (e.g. policy brief), identification of knowledge gap/knowledge cluster, possible interactive database of existing evidence
Specific expertise required	Topic expert

[11] Assumes Collins *et al.* (2014) guidelines followed exactly.

Strengths	Weaknesses
Follows methodological principles of systematic maps Often include searches for grey literature Potentially upgradable into a full systematic review/systematic map without complete repetition Suitable for broad topics	Not as reliable as a full systematic map Protocol typically not externally peer-reviewed Does not usually provide detailed analysis of the content/findings of evidence. Often just shows *what* evidence exists

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7. Systematic map

Summary of method

Structured, step-wise methodology following an *a priori* protocol to comprehensively collate and describe existing research evidence (traditional academic and grey literature).

Systematic reviews should be conducted according to the rigorous standards demanded by review coordinating bodies such as the Collaboration for Environmental Evidence[12] and the Social Care Institute for Excellence SCIE[13] (see references below).

Reporting requirements include: protocol of methods, fates of all articles screened at full text, transparent documenting of all methods used.

Key references

James, K.L., Randall, N.P., Haddaway, N.R. (2016). *A methodology for systematic mapping in environmental sciences.* Environmental Evidence 5, 7.

SCIE systematic mapping guidance www.scie.org.uk/publications/researchresources/rr03.asp

Examples of application

A systematic map on the impacts of agricultural management on soil organic carbon in boreo-temperate regions (Haddaway *et al.* 2015) has been used by government agency in Sweden (Swedish Board of Agriculture, Jordbruksverket) to generate funding for extension work, including a meta-analysis of the impacts on yield.

Haddaway, N.R., Hedlund, K., Jackson, L.E., Kätterer, T., Lugato, E., Thomsen, I.K., Jørgensen, H.B. and Söderström, B., (2015). *What are the effects of agricultural management on soil organic carbon in boreo-temperate systems?* Environmental Evidence, 4(1), p.1.

[12] www.environmentalevidence.org

[13] www.scie.org.uk

Systematic map	
Cost	Staff (3-24 months FTE), subscriptions (database access, article access), software (reference/specialist review management), travel and subsistence, expert (informatician, visualization/database specialist)
Time required	6 months - 4 years Affected by: quantity of literature, availability of staff, response time
Repeatability	High (if conducted and recorded, and archived properly)
Transparency	High (if conducted well, i.e. endorsing organisations)
Risk of bias	Low (if conducted well), acknowledges risk of bias transparently in evidence base and review method
Scale (or level of detail)	Independent of scale
Capacity for participation	Potential consultation throughout
Data demand	High (no reanalysis of existing data)
Types of knowledge	Scientific/technical, explicit
Types of output	Written report plus other communication materials (e.g. policy brief), searchable database of existing evidence, interactive geographical information system (GIS) possible, identification of knowledge gap/knowledge cluster
Specific expertise required	Training, systematic reviewer/informatician, topic expert, visualisation/database specialist

Strengths	Weaknesses
Any type of documented information can be included Very comprehensive - likelihood of missing information is low Protocol externally peer-reviewed and published, increasing transparency and registering intent to conduct the review Conduct and reporting can be supported by coordinating bodies that provide assistance and specialized peer-review Updating is relatively quick if methods have been reported well 'Upgrading' systematic to full systematic review on sub topics with sufficient studies is relatively rapid because much of the work has already been done Coordinating bodies exist that can act as additional endorsement Fully systematic, transparent method with full documentation allowing verification and repeatability Low risk of bias Open access Highly resistant to criticism Usually peer-reviewed Interactive and searchable resources (database/GIS/visualizations) Includes stakeholder engagement Suitable for broad topic areas	High time/resource (staff and expertise/training/access to research papers) requirement Report typically written only in English Systematic maps with large evidence bases may become out-of-date relatively quickly and require updating before full systematic reviews can be undertaken, although this is a relatively rapid task Difficult to interpret main report without additional forms of communication (e.g. factsheets), although these are usually done

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8. Vote-counting

Summary of method

A simple tool used to synthesise findings from multiple studies, by counting the numbers of studies finding positive and negative results. This method is based only on the direction and sometimes significance of the result, and does not critically appraise or differentially weight the studies. Vote counting is limited to answering the question "is there any evidence of an effect?"

There are no formal reporting requirements.

Vote-counting should be avoided whenever possible. It makes it impossible to examine non-significant trends that are only seen to be significant when assessed at a sufficient level of replication across multiple studies. It also treats all studies as having the same level of reliability. It might be considered as a last resort in situations when standard meta-analytical methods cannot be applied (such as when there is no consistent outcome measure).

Key references

Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011].* The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org. Vote counting is described in section 9.4.11

Examples of application

As this is not a recommended knowledge synthesis method, we do not highlight examples of use in policy.

Vote counting	
Cost	Less than a week FTE
Time required[2]	A few days, if data available
Repeatability	Low
Transparency	Low
Risk of bias	High
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	None
Data demand	High
Types of knowledge	Scientific/technical, explicit
Types of output	Often visualised as charts with relative numbers of studies showing positive and negative effects
Specific expertise required	Basic scientific understanding

Strengths	Weaknesses
Quick, but will depend on what comes before (see meta-analysis)	Very high risk of bias Very low scientific rigour: ignores magnitude of effect, ignores trends in non-significant studies, doesn't critically appraise or weight studies

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9. Non-systematic literature review

Summary of method

Literature review that describes (and may appraise) the state/nature of existing evidence, but does not follow a standardised, systematic method.

There are no formal reporting requirements.

Key references

No specific resource provides guidance on the method, as methods are so variable. The following paper suggests how to improve and standardise literature review methods.

Haddaway, N., Woodcock, P., Macura, B., Collins, A. (2015). *Making literature reviews more reliable through application of lessons from systematic reviews.* Conservation Biology 29, 1596-1605.

Examples of application

Many scientific assessment reports commissioned by governments or international institutions follow this method, or a combination of this with 'expert consultation'. For example, the assessment reports of the Intergovernmental Panel on Climate Change (IPCC), the Millennium Ecosystem Assessment (MEA) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) published so far have not followed standardised or peer-reviewed protocols or appraisal methods. Instead, they rely on internal and external extended peer-review of draft report stages as the main element of quality control. They have not documented their detailed methods, or the fate of all articles screened. These steps are required for systematic reviews and systematic maps, and usually also for rapid evidence assessments and scoping reviews.

Non-systematic literature review	
Cost	Varies depending on rigour (a few days to months FTE)
Time required	Varies depending on rigour (a few days to months)
Repeatability	Low
Transparency	Low
Risk of bias	Very high
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Usually none
Data demand	Variable depending on rigour
Types of knowledge	Scientific/technical, opinion-based; explicit
Types of output	Narrative description and reference list

Specific expertise required	Usually requires a topic expert

Strengths	Weaknesses
Fast	No formal methodology
Requires little technical skill	Generally very low transparency precludes verification of methods used and reliability of synthesis
All academics are familiar with their conduct	No critical appraisal of included studies performed
Moderate length documents fairly easy to read and understand	No quantitative analysis of study findings
Can cover a broad subject area	High risk of vote-counting (see Vote-Counting)
	Typically do not include grey literature
	Low comprehensiveness

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10. Expert consultation

Summary of method

The consultation of a designated set of experts, either individually or in a group, to gather judgement, evaluation or opinion. This can use online consultation, in-person meetings, individual interviews, written consultation or group meetings.

There are no formal reporting requirements. Martin *et al.* (2012) suggest four aspects of an expert elicitation exercise that ought to be reported because they are required to determine its comprehensiveness and effectiveness: study design and context, elicitation design, elicitation method, and elicitation output.

Slocum (2003) provides detailed guidance on setting up an expert panel who produce a report, which can be an appropriate form of expert consultation for complex or technical issues.

Key references

Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., LOW-CHOY, S., McBride, M., Mengersen, K. (2012). *Eliciting expert knowledge in conservation science.* Conservation Biology 26, 29-38.

Full text available from: http://caestuaries.opennrm.org/assets/25c6ecae38d70f4c1075fee788e0155b/application/pdf/0611_Martin_etal.pdf

Slocum, N. (2003). *Participatory Methods Toolkit. A practitioner's manual.* United Nations University, King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment

Available from: http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf Accessed 29/01/2017.

Examples of application

This method is extensively used in Government and European Union consultations. An example is during the Environmental Impact Assessment or Strategic Environmental Assessment processes. The method is seldom explicitly documented.

Expert consultation	
Cost	Expenses and compensation of the work time for experts (1 hour – 1 day), staff costs for organising meetings, summarising discussions, writing synthesis (up to 1 week FTE)
Time required	Can be completed in 1 week to 1 month. However a formal expert panel could take longer to deliver its report
Repeatability	Moderate (lower if different individual experts consulted)

Transparency	Moderate. Can be increased by publishing expert names, justification of selection of the experts (why some were not consulted), conflict of interest declarations, procedure of consultation, statements by the experts and results (how the results were interpreted)
Risk of bias	High
Scale (or level of detail)	Any scale, but coarse resolution
Capacity for participation	Moderate and dependent on how the experts are asked to provide their information. For example, individual phone conversation are less participatory than statements in a public hearing process
Data demand	Good overview of expertise/experts in the field needed for adequate selection; can depends on experts access on data
Types of knowledge	All: Scientific, technical, opinion-based, indigenous and local knowledge (if ILK knowledge holders are the 'experts'); explicit and tacit
Types of output	Written and oral statements, reports, can include minority opinions, recommendations
Specific expertise required	Adequate selection of experts (including self-selection biases) , facilitation and moderation skills, ability to handle conflicting expert views

Strengths	**Weaknesses**
Rapid access to knowledge	Not systematic or comprehensive
Can incorporate all types of knowledge	No documentation of the evidence or studies used
Low cost	Subject to bias from individual (self-selected) experts with strong unsubstantiated opinions

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11. Multiple expert consultation with formal consensus method such as Delphi

Summary of method

This method is a subset of expert consultation, representing the most rigorous approach to eliciting expert knowledge. It combines the knowledge of multiple, carefully selected experts into either quantitative or qualitative assessments, using formal consensus methods such as the Delphi process (described and reviewed by Mukherjee et *al.* 2016), or other elicitation techniques, including Cooke's method of weighting experts for their accuracy, described in Martin *et al.* (2012).

Such approaches have been empirically demonstrated to generate estimates for ecological parameters that are more accurate than the estimates of the best-regarded expert in the group (Burgman *et al.* 2011).

Burgman, M.A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., Rumpff, L., Twardy, C. (2011). *Expert status and performance.* PLoS ONE 6, e22998.

Key references

Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., LOW-CHOY, S., McBride, M., Mengersen, K. (2012). *Eliciting expert knowledge in conservation science.* Conservation Biology 26, 29-38.

Mukherjee, N., Hugé, J., Sutherland, W.J., McNeill, J., Van Opstal, M., Dahdouh-Guebas, F., Koedam, N. (2015). *The Delphi technique in ecology and biological conservation: applications and guidelines.* Methods in Ecology and Evolution 6, 1097-1109.

Slocum, N. (2003). *Participatory Methods Toolkit. A practitioner's manual*. United Nations University, King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment.

Available from: http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf Accessed 29/01/2017.

Examples of application

Many examples of the use of Delphi to address environmental issues are described in Mukherjee *et al.* (2015).

Multiple expert consultation with formal consensus method such as Delphi	
Cost	Higher than expert consultation. Takes more time from the experts, but does not have to involve travelling. 1 week – 1 month FTE organising time
Time required	1 week – 2 months. Takes longer than expert consultation because at least two rounds of consultation are usually required
Repeatability	Moderate. Slightly higher than expert consultation

Transparency	Moderate. Can be increased by good reporting of method and elicitation process
Risk of bias	Moderate. Depends on expert selection, but combining expert opinions balances out biases. Biases associated with group decision-making are avoided or reduced by anonymous scoring
Scale (or level of detail)	All scales, level of detail much higher than simple expert consultation
Capacity for participation	Moderate. Can be done with a mixed group of stakeholders with very different areas of expertise
Data demand	Good overview of expertise/experts in the field needed for adequate selection; can depend on experts' access on data
Types of knowledge	Scientific, technical, opinion-based; explicit or tacit
Types of output	Judgements, forecasting, risk assessment
Specific expertise required	Good knowledge of the procedure required, including supporting software etc.

Strengths	**Weaknesses**
Relatively fast	Demands quite a bit of expert time
Relatively low cost	Usually no documentation of the evidence or studies used, but can be combined with summaries or systematic map
Applicable to several types of knowledge	Subject to bias from individual experts with strong unsubstantiated opinions, but much less than basic expert judgement
More rigorous, repeatable and transparent than basic expert consultation	
Reduced risk of bias, compared to other forms of expert judgement	

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12. Causal Criteria Analysis

Summary of method

Causal Criteria Analysis synthesizes understanding of causal linkages in a system, by testing against a set of pre-defined criteria for causality.

It combines pictorial relationships between factors depicting hypothesized or known causal linkages in a system, with literature review to synthesize evidence for specific links in the chain. The diagrams (called influence diagrams, if they include management actions or policy options) are used as scaffolds to synthesize and present evidence. They can also serve as a first step to more elaborate modelling approaches.

The review stage preferably employs the systematic review or rapid evidence assessment method, in which studies are critically appraised and weighted. It could also employ expert consultation, using formal consensus method such as Delphi, or a Bayesian Belief Network approach to elicit knowledge.

The six casual criteria used in the Eco-Evidence software (references below), against which evidence is tested, are: plausibility, evidence of response (e.g. biological response); evidence of a dose-response relationship with the causal agent; consistency of association; evidence of the causal agent found in biota; agreement among hypotheses.

Key references

The Eco-evidence software is one route to conducting Causal Criteria Analysis, and includes a literature review method. This is available from: http://toolkit.ewater.org.au/Tools/Eco-Evidence.

Norris, RH, Webb JA, Nichols SJ, Stewardson MJ and Harrison ET (2012). *Analyzing cause and effect in environmental assessments: using weighted evidence from the literature.* Freshwater Science, 31(1):5-21.

Nichols S., Webb A., Norris R., and Stewardson, M. (2011). *Eco Evidence analysis methods manual: a systematic approach to evaluate causality in environmental science.* eWater Cooperative Research Centre, Canberra.

Examples of application

The causal criteria approach was famously used to demonstrate the health effects of smoking in the US.

USDHEW (1964). *Smoking and Health.* Report of the Advisory Committee to the Surgeon General of the Public Health Service. U.S. Dept. Health Education and Welfare, Washington, U.S.

Causal Criteria Analysis	
Cost	Staff time: One month to several years FTE. Stakeholder time and travel expenses Depends on: • Whether or not a formal literature review stage is included (see costs for Systematic Review or Rapid Evidence Assessment) • Number of stakeholders/experts involved • Level of disagreement among stakeholders/experts • Level of detail: text or tabular explanation of the CCA, and number of nodes (factors) and relationships (links) in CCA • Facilitator/moderator, if done in participatory mode • Scale of the problem (no of sectors, countries involved/addressed)
Time required	The system diagram can be done within one day (or less, e.g. if done as desk research). Reviews of evidence for each link take 1 week - 24 months, depending on method
Repeatability	Moderate. If done with two different groups of people or individuals, the chain will likely differ
Transparency	High (if well documented)
Risk of bias	Moderate. Depends on representativeness of knowledge holders involved, and whether individual input is incorporated or obtained in group discussion
Scale (or level of detail)	Flexible Potential to address detailed questions or broader problems
Capacity for participation	Potential to be moderate to high
Data demand	Low Can point to further data demands Requires expert judgement Requires stakeholder input if done in participatory manner
Types of knowledge	Scientific, technical, opinion-based; explicit, tacit
Types of output	Flow diagram, causal chain, can be an influence diagram that includes possible management actions or policy decisions Explanatory report/information attached
Specific expertise required	Does not necessarily require specific expertise For participatory CCA, need skills in creating teams and in facilitation

Strengths	Weaknesses
System perspective of a problem: can include multiple scales, multiple sectors, multiple actors	Can be biased, depending on facilitation and representativeness
Flexible level of complexity: can be done in a very simple manner by one person or in a complex participatory manner	Final results are only as robust as the literature review method employed
Visualization	
Can be used transparently	
Good for a starting point/ scoping/prototyping, can lead into a quantitative model	
Can point to data/information needs	
Can inform decision/policy making especially if done as an influence diagram that includes one or more possible actions or policies	

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13. Bayesian Belief Networks

Summary of method

A semi-quantitative modelling approach that combines empirical data with expert knowledge to calculate the probability of a specific outcome or set of outcomes.

Similar to the Causal Criteria Analysis, the method first builds a visual representation of the system. Probabilities for each link can be based on expert judgement, literature review, or a prescribed mechanistic model. The BBN model can then generate a range of probabilities for the final outcome, based on the underlying system.

The main output is a diagrammatic interpretation of a system showing probabilistic relationships and outcomes within a causal chain.

This method explicitly incorporates uncertainty about linkages in a causal chain via conditional probabilities. For example, a BBN could quantify likelihood of storm events large enough to impact coastal ecosystems.

Key references

Cooper, G. F., & Herskovits, E. (1992). *A Bayesian method for the induction of probabilistic networks from data.* Machine learning, 9(4), 309-347.

Landuyt, D., Broekx, S., D'hondt, R., Engelen, G., Aertsens, J., & Goethals, P. L. (2013). *A review of Bayesian belief networks in ecosystem service modelling.* Environmental Modelling & Software, 46, 1-11.

McCann, R. K., Marcot, B. G., & Ellis, R. (2006). *Bayesian belief networks: applications in ecology and natural resource management.* Canadian Journal of Forest Research, 36(12), 3053-3062.

Examples of application

Nyberg *et al.* (2006) present a case study of a BBN used during adaptive management of forest lichens in Canada.

Thorne *et al.* (2015) describe the use of a BBN with stakeholders managing tidal marshes across San Francisco Bay, USA.

Nyberg, J. B., B. G. Marcot, and R. Sulyma. (2006). *Using Bayesian belief networks in adaptive management.* Canadian Journal of Forest Research 36:3104-3116. NOT OPEN ACCESS.

Thorne, K. , B. J. Mattsson, J. Takekawa, J. Cummings, D. Crouse, G. Block, V. Bloom, M. Gerhart, S. Goldbeck, J. O'Halloran, B. Huning, N, Peterson, C. Sloop, M. Stewart, K. Taylor, and L. Valoppi. (2015). *Collaborative decision-making framework to optimize resilience of tidal marshes in light of climate change uncertainty.* Ecology and Society 20 (1): 30. [online] URL: http://www.ecologyandsociety.org/vol20/iss1/art30/

Bayesian Belief Networks	
Cost	Staff: 1 week – 3 months FTE Depends on • Software used, some freeware and trial versions available • The number of stakeholders/experts involved • Level of disagreement among stakeholders/experts • Number of revision rounds→ depending on further use of the BBN • Level of detail: text or tabular explanation of the BBN, and number of nodes (factors) and relationships (links) in BBN • Facilitator/moderator, if done in participatory mode • Need and availability of existing predictive models to inform BBN structure and probabilities • If Bayesian decision network (BDN), then availability of utility values (value trade-offs in the case of multiple objectives) • Scale of the problem (no of sectors, countries involved/addressed)
Time required	1 week to 3 months If preparatory work is done (causal chain ready for conversion to BBN, elicitation process set up if needed, predictive models ready if relevant and available, facilitators ready if participatory), can be done in 1 day. Several days of preparatory time are likely to be required
Repeatability	Low. If you do it with two different groups of people or individuals, the BBN structure (if done from scratch) and probabilities will likely differ
Transparency	Moderate. Allows for mathematical rigor and sensitivity analysis to evaluate robustness of outcomes or recommendations to uncertainty. BUT quantification of the system relationships (and stakeholder values in the case of a BDN) can be challenging for non-technical stakeholders Depends on level of documentation for the reasoning and methods used to develop and parameterize the BBN

Risk of bias	Moderate. Quantification if done properly can avoid biases compared to purely qualitative approaches Depends on: • representativeness of stakeholders/experts • whether individual input is incorporated or obtained in group discussion • quality of any data and predictive models incorporated • quality of underlying causal chain conceptual model
Scale (or level of detail)	Flexible
Capacity for participation	Moderate. Depends on who is engaged. Could be just experts
Data demand	Depends on available predictive models and literature data Can point to further data demands Requires expert judgement Requires quantified stakeholder values (BDN)
Types of knowledge	Scientific, technical, opinion-based; tacit
Types of output	Flow diagram, causal chain Likelihoods (probabilities) of particular outcomes. For example, 80% chance that fish abundance will be <50 if a particular policy option is implemented Quantified expected stakeholder satisfaction associated with alternative management/policy options (BDN) Explanatory report/information attached
Specific expertise required	Requires an analyst with background in quantitative modelling especially statistics and probability, plus familiarity with at least one BBN software For participatory expert/stakeholder-based parameterization, requires skills in creating teams, facilitation, parameterization For parameterization based on existing literature or predictive models, need topic experts familiar with any underlying predictive models and/or literature

Strengths	Weaknesses
Potential for system perspective of a problem: can include multiple scales, multiple sectors, multiple actors	Can be biased, depending on facilitation and representativeness
Flexible level of complexity: can be done in a very simple manner by one person or in a complex participatory manner	Requires quantitative modelling skills to set up and parameterize BBN
Visualization	Requires topical expert input
Can be used transparently, if done in a participatory manner and BBN is kept simple enough so that all participants can understand the underlying mathematics	Requires knowledge-holder input if developed in participatory manner or as a BDN
Provides probabilities of outcomes	
Clearly and quantitatively represents uncertainty	
Can directly provide policy/management recommendations (BDN)	
Can be used to quantify value of collecting more information / research to inform a recommendation (BDN)	

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14. Focus groups

Summary of method

Structured discussion of an issue by a small group six to ten of people, led by a skilled moderator. The group is purposively selected usually to involve different stakeholders and/or potentially differing perspectives. The joint discussion allows participants to consider and react to arguments put forward by other participants so it allows examination of group dynamics and opinion formation.

Focus groups are regarded as an appropriate method for evaluating attitudes, knowledge and experiences, although features of the focus group method should be reported to allow better interpretation of results (Orvik *et al.* 2013). Focus groups can also be used to gather information form a specific group, to build scenarios in a choice experiment method for instance, or test questions or issues for a quantitative survey.

Orvik A, Larun L, Berland A, Ringsberg KC (2013). *Situational factors in focus group studies: a systematic review.* Int J Qual Methods 12:338–358.

Key references

There are many free online resources providing guidance on how to conduct focus groups. For example, Slocum (2003) provides detailed guidance on how to run focus groups.

Freeman (2006) provides a useful summary of advice on best practice for focus groups in research, arguing that best practice differs according to the underlying assumptions about the nature of knowledge being sought.

Freeman, T. (2006). *"Best practice" in focus group research: Making sense of different views.* Journal of Advanced Nursing, 56(5), 491–497.

Slocum, N. (2003). *Participatory Methods Toolkit. A practitioner's manual.* United Nations University, King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment

Available from: http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf Accessed 29/01/2017.

Examples of application

Saynajoki E-S, Heinonen J, Junnila S (2014). *The Power of Urban Planning on Environmental Sustainability: A Focus Group Study in Finland.* Sustainability 6 (10), 6622-6643.

Focus groups	
Cost	Staff time: 2 days per focus group FTE Travel expenses and venue costs for group members

Time required	Event itself 0.5 to 1 day for each focus group. A series of focus groups probably 2 weeks to 1 month, to allow for selecting group members and settings
Repeatability	Low
Transparency	Low to moderate. Reporting of methods tends to be poor (Orvik *et al.* 2013)
Risk of bias	High. The method exploits group dynamics, so it very subject to social biases, as well as the bias from group member selection
Scale (or level of detail)	Good: local/regional More problematic: national/EU-level as it then depends on how well representatives represent their constituencies
Capacity for participation	Moderate to high. Breadth could be good, if a representative sample of stakeholders/participants but depth depends heavily on the ways in which the process is organised and facilitated
Data demand	Stakeholder analysis, and analysis of the context (what is the problem, what is the political context), visualisation tools like maps and data about issues at stake
Types of knowledge	All types of knowledge can be captured. Tacit
Types of output	Descriptive accounts, judgements, information about interests, concerns and values
Specific expertise required	Excellent process organisation and facilitation skills

Strengths	**Weaknesses**
Low cost and quick	High risk of bias
Allows detailed evaluation of opinion and attitudes at local/regional scale	Not necessarily representative or accurate
The structured process allows involvement of a range of stakeholders	Important groups can be excluded if disenfranchised, because it is face to face
Can be accommodated to evolving circumstances	Risk of conflict; challenging to handling differing views

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15. Discourse analysis

Summary of method

Discourse analysis is a structured method for investigating conflicts and alliances among different knowledge holders or stocks of knowledge when discourses are emerging. The aim is to identify the key issues and actors, distinguish between certain and uncertain knowledge, and determine which knowledge claims are points of conflict between different groups in society and the sciences.

The focus is on arguments, procedures or putative facts that are seen as correct or true by the actors under analysis, rather than on whether they are true. Discourse analysis can therefore reveal why a particular understanding of a given environmental problem at some point gains dominance and is seen as authoritative, while other understandings are discredited.

Key references

There are no international methodological guidelines or standards for conducting discourse analysis. There are different traditions, based on different underlying theories, or understandings of the meaning of discourse (Antaki *et al.* 2003; Hewitt 2009). The following references provide information about possible methods. Hewitt (2009) describes a ten-step approach to structured discourse analysis.

Antaki, C., Billig, M.G., Edwards, D. and Potter, J.A., (2003). *''Discourse Analysis Means Doing Analysis: A Critique of Six Analytic Shortcomings'',* Discourse Analysis Online,

https://extra.shu.ac.uk/daol/articles/open/2002/002/antaki2002002-paper.html

Hewitt S. (2009). *Discourse Analysis and Public Policy Research.* Centre for Rural Economy Discussion Paper Series No. 24. http://ippra.com/attachments/article/207/dp24Hewitt.pdf

Phillips, N., & Hardy, C. (2002). *Discourse analysis: Investigating processes of social construction (Vol. 50).* Sage Publications. NOT OPEN ACCESS.

Examples of application

While there are many examples of research to evaluate or understand the development of environmental policies, we have not found an example of discourse analysis being used as a knowledge synthesis method in a science-policy interface.

Use this example:
http://www.tandfonline.com/doi/abs/10.1080/1523908X.2016.1266930?journalCode=cjoe20

Discourse analysis	
Cost	Several person-months for acquiring and analysis of interactions and texts (interviews, protocols, newspaper articles, policy documents, ...)
Time required	2-10 months
Repeatability	Rather high, but interpretation is involved; framing matters a lot
Transparency	Can be quite high
Risk of bias	Moderate. Depends on what material you include/leave out, interpretative bias can be limited by inter-coder agreement
Scale (or level of detail)	All scales, generic arguments rather than detailed opinions
Capacity for participation	Low. Scope of informants can be broad, participation in actual analysis of data is limited (usually carried out by a discourse analyst, no participation of outside actors usually involved)
Data demand	Adequate documents and possibly interviews required
Types of knowledge	All
Types of output	Narrative description of the understanding and perceptions of issues/problems, and the ways in which different societal groups understand them
Specific expertise required	Discourse analysis methods and approach; background in interpretative policy analysis

Strengths	Weaknesses
Can address highly controversial issues	Only synthesizes perceived knowledge, rather than actual scientific evidence
Covers all types of knowledge	
Identifies specific points of contention and uncertainty	
Can be used to set research priorities, or communication priorities	

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16. Joint Fact Finding

Summary of method

Joint Fact-Finding is a process in which separate coalitions of scientists, policy-makers and other stakeholders with differing viewpoints and interests work together to develop data and information, analyse facts and forecasts, and develop common assumptions and informed opinions (van Buuren *et al.* 2007). Finally, they can use the information they have developed to reach decisions together.

A comparatively small group can be involved, but all opposing positions need to be represented.

A similar process called 'Double sided critique' is also considered by Pullin *et al.* (2016).

Key references

Schultz, Norman. *"Joint Fact-Finding."* Beyond Intractability. Eds. Guy Burgess and Heidi Burgess. Conflict Information Consortium, University of Colorado, Boulder. Posted: July 2003. http://www.beyondintractability.org/essay/joint-fact-finding

McCreary, S. T., Gamman, J. K., & Brooks, B. (2001). *Refining and testing joint fact-finding for environmental dispute resolution: Ten years of success.* Conflict Resolution Quarterly, 18(4), 329-348.

Examples of application

Joint fact-finding was used by the Scheldt Estuary Development Project (ProSes), during the development of joint policy for the Scheldt Estuary in Belgium (van Buuren *et al.* 2007).

It was also used with infrastructure stakeholders in Rotterdam, to ascertain if, how and when the transport infrastructure would need to be adapted to climate change (Schenk *et al.* 2016). The process was convened by the municipality of Rotterdam, and funded by the City of Rotterdam and Dutch Ministry of Infrastructure and Environment.

Schenk, T., Vogel, R. A., Maas, N., & Tavasszy, L. A. (2016*). Joint fact-finding in practice: Review of a collaborative approach to climate-ready infrastructure in Rotterdam.* EJTIR, 16(1), 273-293.

van Buuren, A., Edelenbos, J., & Klijn, E. H. (2007*). Managing knowledge in policy networks. Organising joint fact-finding in the Scheldt Estuary.*

Joint Fact Finding	
Cost	Resources to run the process, and maybe also to fund new research activity Usually requires a skilled facilitator or mediator
Time required	Usually rather time-consuming; however depends on where the in the process it is used and the nature of the question (complex and contested vs. relatively straightforward)
Repeatability	Medium. Outcome depends on personalities involved; process rather than “a method”
Transparency	Creating protected spaces might sometimes be needed, especially in mediation; however, the result and the process can be communicated transparently
Risk of bias	High if not all relevant groups included and the process is not well facilitated
Scale (or level of detail)	Any
Capacity for participation	Can be limited to relevant scientists/stakeholders holding opposing views but can also include elements to involve the general public
Data demand	The process does not require any data at the outset. The subsequent data demands depend on what is requested by participants, and the question to be addressed
Types of knowledge	All
Types of output	Shared understanding and clarity about remaining disagreements Policy learning
Specific expertise required	Qualified facilitators or mediators are essential for success

Strengths	Weaknesses
Enables policy learning	Managing competing interests can be difficult, and needs highly skilled facilitation
Identifies which 'facts' are disputed	Ability to invest resources can be asymmetric among stakeholders, creating imbalance of 'power'
Potentially provides a process to reach agreement through co-designed research	Requires mutual trust and respect, which cannot always be achieved
Recognises that knowledge isn't 'value-free' and can be interpreted differently by those with different interests	Knowledge and learning are held within a small, temporary network and may not be retained in decision-making institutions
Can build mutual trust and respect among stakeholders	

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17. Scenario analysis

Summary of method

Scenario Analysis formulates assumptions about future developments in one connected storyline. Scenarios are consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments.

Qualitative storylines for the future development of complex systems can be integrated with quantitative modelling. "Scenarios and models play complementary roles, with scenarios describing possible futures for drivers of change or policy interventions and models translating those scenarios into projected consequences for nature and nature's benefits to people." IPBES (2016).

Scenarios are more likely to lead to read policy outcomes if they use participatory approaches to involve stakeholders throughout, from the initial phase of problem definition and feature frequent exchanges between scientists and stakeholders.

Participatory scenario development aims to supplement and synthesize existing data and formalized knowledge with other relevant forms of stakeholder knowledge.

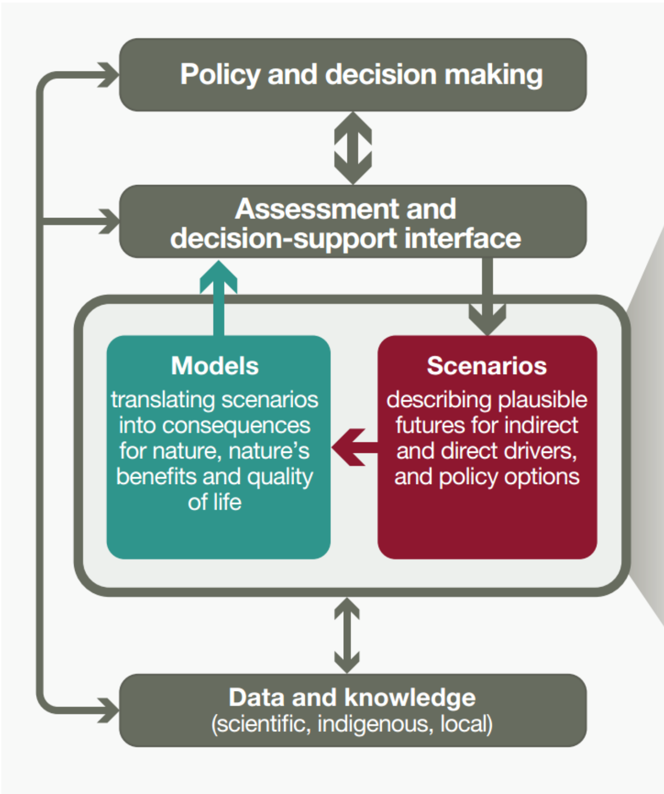

Figure 1 shows the roles of scenarios and modelling in informing policy and decision making. Scenarios and models are directly dependent on data and knowledge for their construction and testing, and provide added value by synthesizing and organizing knowledge. Source: IPBES (2016).

Key references

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES 2016) assessment report on scenarios and modelling presents a best-practice ‘toolkit’ of the approaches that can be used to decide on policies and actions by Governments, the private sector and civil society.

Slocum (2003) provides detailed guidance on how to develop qualitative scenarios through participatory workshops.

IPBES (2016). *The methodological assessment report on scenarios and models of biodiversity and ecosystem services.* S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L. A. Acosta, H. R. Akçakaya, L. Brotons, W. W. L. Cheung, V. Christensen, K. A. Harhash, J. Kabubo-Mariara, C. Lundquist, M. Obersteiner, H. M. Pereira, G. Peterson, R. Pichs-Madruga, N. Ravindranath, C. Rondinini and B. A. Wintle (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 348 pages. http://www.ipbes.net/work-programme/scenarios-and-modelling

Slocum, N. (2003.) *Participatory Methods Toolkit. A practitioner’s manual.* United Nations University, King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment. Available from: http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf Accessed 29/01/2017.

Examples of application

The following two examples are used in IPBES (2016) to illustrate the use of different types of scenario at global and local scales.

Global scale

The Global Biodiversity Outlook 4 assessment of the Convention on Biological Diversity, used to evaluate the Strategic Plan for Biodiversity 2011-2020, relied heavily on target-seeking scenarios to explore ways of achieving multiple sustainability objectives for 2020.

IPBES(2016), Figure SPM.3.

Local/regional scale

Policy-screening scenarios were used to explore future land use in the Thadee watershed in southern Thailand, where the water supply for farmers and household consumption has been degraded by the conversion of natural forests to rubber plantations (Trisurat, 2013). Scenarios were built using local datasets and knowledge. The municipality has agreed to find means of collecting a conservation fee based on payments for watershed services to fund forest protection, reforestation or conversión to mixed cropping. IPBES (2016), Figure SPM.4.

Many examples were presented at a conference on scenarios and models of biodiversity and ecosystem services, France, 2016 (ScenNet, 2016).

ScenNet (2016). International Conference on Scnenarios and Models of Biodiversity and Ecosystem Services in Support of Decision-Making. Abstract Book. https://scennet2016.sciencesconf.org/data/pages/ScenNet2016_Book_of_Abstracts.pdf

Trisurat, Y., (2013). *Ecological Assessment: Assessing Conditions and Trends of Ecosystem Services of Thadee watershed, Nakhon Si Thammarat Province (in Thai with English abstract).* Final Report submitted to the ECO-BEST Project. Bangkok, Faculty of Forestry, Kasetsart University.

Scenario analysis	
Cost	Cost depends on: • The scope of the scenario exercise, e.g. scale of the problem, number of sectors, countries involved/addressed and level of detail • Software used, some freeware and trial versions available • Number of stakeholders/experts involved • Level of disagreement among stakeholders/experts • Number of revision rounds • Availability of existing scenarios A facilitator or moderator is needed , if participatory
Time required	Simple scenarios can be developed in 2-5 days with few resources, but the entire organising process can take up to 6 months. (To analyse complex systems, longer process is needed, involving more knowledge-holders and stakeholders
Repeatability	Low. If done with two different groups of people, the scenarios will likely differ
Transparency	Depends on documentation of the process (e.g. how far are assumptions made explicit), the data used and the participants involved. Complex scenarios with quantitative modelling can have low transparency to those not involved in developing them
Risk of bias	Medium. Depends on representativeness of stakeholders/experts involved, and whether individual input is incorporated or obtained in group discussion (greater bias likely from group discussion)
Scale (or level of detail)	Flexible, from local to global, but different methods appropriate to different scales
Capacity for participation	High. Participation is part of the method for qualitative scenario building

Data demand	Qualitative scenarios depend on expert/stakeholder knowledge (e.g. tacit knowledge), which can be combined with other sources of information (e.g. from quantitative models, literature reviews, or interviews) Quantitative scenarios depend on quantitative data and often have high data demand
Types of knowledge	Scientific/technical, opinion-based, indigenous and local; tacit and explicit (ALL)
Types of output	Report (qualitative and/or quantitative information), maps (including quantitative information), tables and graphs (including economic scenarios)
Specific expertise required	Topic experts needed. Facilitator required for participatory process

Strengths	**Weaknesses**
Option for including stakeholders in the assessment process Using participatory methods, local or tacit knowledge can be incorporated Flexible structure for analyses with the possibility to easily adapt the method to various contexts 'Target-setting' scenarios can be used to identify desirable future developments and map out the steps needed to achieve a desired future outcome Many different approaches are available, to suit different policy and decision contexts *Quantitative scenarios, with integrated modelling* Very robust results Used for complex, quantitative analysis of impacts, with multiple inputs or outputs Provide fixed structure for analyses (e.g. most economic models are based on national accounts)	Can be time-consuming. Lowering the time used to build scenarios trade-offs with time for involving stakeholders A qualitative approach should put a strong emphasis on the selection of suitable participants/ experts; in practice this can be challenging Requires substantial technical knowledge and capacity Data and information from disparate sources have to be collected and interpreted *Quantitative scenarios, with integrated modelling* Risk that assumptions not set out transparently Very high resource requirements All models require complete data sets and results depend on input data

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18. Structured Decision Making

Summary of method

Structured Decision Making (SDM) is a well-defined method for analyzing a decision by breaking it into components including the objectives, possible actions, and models linking actions to objectives. It aims to compare possible actions in terms of one or more objectives.

It provides transparency by specifying each of these components and providing information that a decision-maker can use to implement and defend a decision.

This method can incorporate other knowledge synthesis methods. For example, Thorne *et al.* (2012) describe a process that uses a Bayesian Belief Network in the context of Structure Decision Making. Expert consultation with elicitation is often used to quantify predictive relationships as part of SDM.

SDM is founded on principles of value-focused thinking and decision analysis and can be conducted in a participatory manner with decision-makers, stakeholders, and experts. It can also provide a basis for adaptive management.

Structured Decision Making typically involves a series of iterative steps called PrOACT (Problem framing, Objectives, Actions, Consequences, and Tradeoffs).

Key references

The method is described in detail in two books (Conroy and Peterson, 2012; Gregory *et al.* 2012). There is an open access online course describing each step in detail, through videos and handouts (Runge *et al.* 2011).

Conroy, M. J. and J. T. Peterson. (2012). *Decision making in natural resource management: A structured, adaptive approach.* John Wiley & Sons, Hoboken, New Jersey, USA. NOT OPEN ACCESS.

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., & Ohlson, D. (2012). *Structured decision making: a practical guide to environmental management choices.* John Wiley & Sons. NOT OPEN ACCESS.

Runge, M. C., J. F. Cochrane, *et al.* (2011). *An overview of structured decision making, revised edition.* U.S. Fish and Wildlife Service, National Conservation Training Center, Shepherdstown, West Virginia, USA. [online videos] https://training.fws.gov/courses/ALC/ALC3183/resources/index.html

Examples of application

SDM is used to inform decisions by US state and federal natural resource management agencies, including Fish and Wildlife Service, National Marine Fisheries Commission, and US Army Corps of Engineers. It has also been used to inform regional decision-making in the San Francisco Bay Estuary and multi-party river management in southern British Columbia and northern Alberta.

It has been implemented in multi-stakeholder planning processes to inform decisions by a private hydroelectric company, local watershed organization, and a township in British Columbia. Also used to inform management decisions by trans-boundary protected areas in Europe involving broad-scale conservation issues.

Some published examples of application to real-world decision-making:

Compass Resource Management. 2015. Feature projects. Compass Resource Management, Vancouver, British Columbia, Canada. http://www.compassrm.com/feature_projects.php

Dalyander, P. S., M. Meyers, B. Mattsson, *et al.* (2016). *Use of structured decision-making to explicitly incorporate environmental process understanding in management of coastal restoration projects: Case study on barrier islands of the northern Gulf of Mexico.* Journal of Environmental Management 183: 497-509.

Gannon, J. J., T. L. Shaffer, and C. T. Moore. (2013). *Native Prairie Adaptive Management: a multi-region adaptive approach to invasive plant management on Fish and Wildlife Service owned native prairies.* US Geological Survey, Reston, Virginia, USA. https://pubs.er.usgs.gov/publication/ofr20131279

Gregory, R., & Long, G. (2009). *Using structured decision making to help implement a precautionary approach to endangered species management.* Risk Analysis, 29(4), 518-532.

Ohlson, D. W., McKinnon, G. A., & Hirsch, K. G. (2005). *A structured decision-making approach to climate change adaptation in the forest sector.* The Forestry Chronicle, 81(1), 97-103.

Ralls, K., & Starfield, A. M. (1995). *Choosing a Management Strategy: Two Structured Decision-Making Methods for Evaluating the Predictions of Stochastic Simulation Models.* Conservation Biology, 9(1), 175-181.

Thorne, K. M., B. J. Mattsson, *et al.* (2015). *Collaborative decision-analytic framework to maximize resilience of tidal marshes to climate change.* Ecology and Society 20. http://www.ecologyandsociety.org/vol20/iss1/art30/

Structured Decision Making	
Cost	Staff time: at least 1 month (FTE). Needs two coaches trained in SDM, one with skills in quantitative decision analysis, and participants committing their time (see below) to participate throughout the process including at least one decision maker Cost depends on • Scale of the problem and sectors, countries involved/addressed • The number of stakeholders/experts involved • How well the decision problem has already been framed by the stakeholders/experts • Level of disagreement among participants • Level of detail discussed, specified, and documented • Quality of facilitator/SDM coach

	• Decision analysis software needed
Time required	Duration typically at least 4 weeks: one week to frame the decision problem and form an appropriate team to address it, one week to develop a prototype decision framework, and two weeks to develop a final prototype in consultation with team members
Repeatability	If conducted with two different teams, the decision structure and in particular the quantitative components will likely differ
Transparency	High (if properly done). SDM is designed to promote transparency and defensibility of the decision-making process Depends on the quality of the SDM coaches, level of transparency desired by team members, and time availability of team members to provide the desired level of transparency
Risk of bias	Medium. Depends on: • Representativeness of stakeholders/experts • Whether individual input for the decision analysis is incorporated or obtained in group discussion • Quality of any data and predictive models incorporated
Scale (or level of detail)	Flexible; can address detailed fine-scaled decisions to broader transnational decisions
Capacity for participation	Flexible; can be done by one person trained in SDM or by a team of one or more decision-makers, stakeholders, and experts. Increasing number of participants beyond 10 typically requires a professional facilitator
Data demand	Information needs shift from qualitative to quantitative from the earlier to later steps. These needs depend on the desired level of transparency (see above). Can be done without literature review or detailed data analyses and instead rely on stakeholder and expert elicitation, but it can also incorporate data from the literature or existing models
Types of knowledge	Can incorporate scientific, indigenous, expert, and practitioner knowledge to help describe, decompose, and analyse the decision. No known cases where lay (public) knowledge has been incorporated e.g. through surveys, but it could be
Types of output	Concise decision question; objectives hierarchy; influence diagram; lists and definitions of ultimate objectives, management options, and external factors that are at least partly beyond control of managers; Bayesian belief/decision network; consequence table; weights of importance among objectives; expected utilities of management options

	These outputs can be presented user-friendly concise to detailed written reports and interactive websites
Specific expertise required	Requires one person with background in quantitative decision analysis, and one or more experts who can characterize and quantify the key sources of uncertainty that can influence the decision

Strengths	Weaknesses
Can cope with high levels of uncertainty about system dynamics and conflicting stakeholder values	Quality of outputs depends on the quality and training of the SDM coach
Good capacity for participation of stakeholders	Depends on the availability and trust of the participants, including decision-makers, stakeholders, and experts
Can incorporate diverse types of knowledge, including qualitative and quantitative information	Often relies on expert elicitation to quantify relationships between specified actions and objectives, as numerical models and data are often lacking
Outputs can be scientifically defensible and understandable by non-technical audiences	Often simplifies a problem so that it is feasible to analyse. Clear documentation of the simplifying process is needed to maintain transparency
Highly transparent (if done well)	
'Bottom-up', driven by decision-maker needs and wishes	
Useful for identifying and overcoming barriers to decision making by deconstructing a decision problem into component parts	

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19. Collaborative Adaptive Management

Summary of method

Collaborative Adaptive Management (CAM) is a structured/flexible, stepwise, transparent approach that includes the iteration of knowledge synthesis, most often using collaborative methodologies, such as participatory scenario building, joint fact-finding and/or multi-criteria analysis. New knowledge is then generated, through the selection, application and monitoring of policies or management strategies.

CAM differs from other knowledge synthesis methods in a key aspect. Instead of aiming to identify single, broadly-applicable, optimal solutions, it aims to identify flexible solutions that are resilient to errors and uncertainty. The initial phase of CAM represents a specific type of knowledge synthesis, but the overall approach goes beyond synthesis to locally or specifically relevant knowledge generation.

Key references

The following methodological tools and guidance are available to support and guide implementation of CAM.

Miradi: Adaptive Management Software for conservation projects. www.miradi.org

The NeWater project (European Comm. Contract No 511179) and the Global Water System Project provide an online course in Adaptive Management for water resources: http://www.newatereducation.nl/

Examples of application

The US Department of Interior used CAM to carry out its responsibilities under the Grand Canyon Protection Act of 1992 to monitor the operation of the Glen Canyon Dam and mitigate any significant environmental impacts. There is not agreement over whether this landmark example of CAM was a success, or achieved its environmental objectives. Susskind *et al.* (2012) argue that it was not a success, because the process was flawed and best practice was not followed. Specifically, they argue that joint fact-finding should be used as part of CAM, to deal with scientific uncertainty.

Other examples of CAM used to improve the governance of water resources management and wetland conservation are presented in Méndez *et al.* (2012) and Kallis *et al* (2009).

Useful reviews of the utility and practical implementation of Collaborative Adaptive Management are provided by Westgate *et al.* (2013), Scarlett (2013) and Susskind *et al.,* (2012).

Kallis, G., Kiparsky, M., & Norgaard, R. (2009). *Collaborative governance and adaptive management: Lessons from California's CALFED Water Program.* Environmental Science & Policy, 12(6), 631-643.

Méndez PF, Isendahl N, Amezaga JM, Santamaría L (2012). *Facilitating transitional processes in rigid institutional regimes for water management and wetland conservation: experience from the Guadalquivir Estuary.* Ecol Soc 17:26.

Scarlett, L. (2013). *Collaborative adaptive management: challenges and opportunities.* Ecology and Society, 18(3).

Susskind, L., A.E. Camacho and T. Schenk (2012). A Critical Assessment of Collaborative Adaptive Management in Practice. Journal of Applied Ecology, 49(1): 47-51.

Susskind, L., A.E. Camacho and T. Schenk (2010). Collaborative Planning and Adaptive Management in Glen Canyon: A Cautionary Tale. Columbia Journal of Environmental Law, 35(1): 1-54.

Westgate MJ, Likens GE, Lindenmayer DB (2013). *Adaptive management of biological systems: A review.* Biological Conservation 158:128-139.

Collaborative Adaptive Management	
Cost	Staff (3-12 months FTE if restricted to diagnosis and planning; 12-48 months FTE including a first learning-by-doing cycle), travel and subsistence (for workshops and, if necessary, to interview stakeholders), software (for complex issues requiring knowledge-mapping visualization and/or dynamic modelling tools), expert (facilitation of collaborative knowledge mapping or collaborative modelling, incl. visualization tools) Affected by: available evidence; knowledge gaps and uncertainties; need for specialist expertise; complexity of the question; Capacity for conflicts among agencies and/or stakeholders
Time required	3-12 months if restricted to diagnosis and planning 24-60 months including a first learning-by-doing cycle Affected by: number and scale of interventions/actions, complexity of socio-natural system, availability of staff, response time
Repeatability	High (if done and recorded, and archived properly)
Transparency	High (if properly done). CAM is specifically designed to ensure transparency, legitimacy and trust among stakeholders Risk: In the absence of adequate design and implementation of collaborative work, AM may be used to obscure rather than address underlying conflicts - thus reducing transparency
Risk of bias	Low (if done well and with enough time/resources). CAM acknowledges bias as inherent to knowledge and designs learning-by-doing strategies to evaluate inherent assumptions, thus reducing the risk of failure
Scale (or level of detail)	Independent of scale (any)
Capacity for participation	Very high (if done well). All key stakeholders involved in collaborative modelling and decision-making. Several opportunities for open consultation and/or participation along the diagnostic phase and learning cycle

Data demand	Low in the initial phase, though it should aim to include all relevant information, know-how and expertise available. High in the implementation (learning-by-doing) phase
Types of knowledge	All
Types of output	Collaborative knowledge maps, identification of uncertainties and knowledge gaps, adaptive management strategy, policy briefs These outputs can be presented user-friendly written reports, interactive website of narrative evidence, short documentary films and/or other communication materials
Specific expertise required	CAM specialist (incl. interviewing and facilitation), topic expert, modelling specialist

Strengths	**Weaknesses**
Stakeholders are involved in a proactive, structured way High transparency and participation Allows for a way forward when insufficient evidence precludes the identification of an optimal solution Designed to accommodate to counterintuitive effects, uncertainty and evolving circumstances Designed to handle differing views and facilitate conflict resolution, though it might be challenging in wicked problems and longstanding socio-environmental conflicts	Depends on trust and willingness to participate, as all stakeholders must be involved Implementation of learning-by-doing cycle depends on sufficient top-down and bottom-up support Needs agreement on an overarching goal and how to measure progress towards it

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20. Participatory mapping

Summary of method

Participatory mapping defines a set of approaches and techniques that combine the tools of modern cartography with participatory methods to represent the spatial knowledge of local communities. It is based on the premise that local inhabitants possess expert knowledge of their local environments that can be expressed in a geographical framework, which is easily understandable and universally recognised.

Key references

The International Fund for Agricultural Development (IFAD) has produced a guidance document that identifies good practice, evaluates participatory mapping tools (Annex A) and lists project examples (Annex B).

International Fund for Agricultural Development (2009). *Good Practices in Participatory Mapping* https://www.ifad.org/documents/10180/d1383979-4976-4c8e-ba5d-53419e37cbcc

Community Maps — A Platform for Participatory Mapping

http://europe.foss4g.org/2014/content/community-maps-%E2%80%94-platform-participatory-mapping.html

Examples of application

Beverly, J. L., Uto, K., Wilkes, J., & Bothwell, P. (2008*). Assessing spatial attributes of forest landscape values: an internet-based participatory mapping approach.* Canadian journal of forest research, 38(2), 289-303.

Chambers, R. (2006). *Participatory mapping and geographic information systems: whose map? Who is empowered and who disempowered? Who gains and who loses?* The Electronic Journal of Information Systems in Developing Countries, 25.

Fagerholm, N., & Käyhkö, N. (2009). *Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania.* Fennia-International Journal of Geography, 187(1), 43-60.

Forrester, J., Cook, B., Bracken, L., Cinderby, S., & Donaldson, A. (2015). *Combining participatory mapping with Q-methodology to map stakeholder perceptions of complex environmental problems.* Applied Geography, 56, 199-208.

Mapedza, E., Wright, J., & Fawcett, R. (2003). *An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping.* Applied Geography, 23(1), 1-21.

Sletto, B. I., Hale, C. R., Middleton, B. R., Nygren, A., Rodríguez, I., Schroeder, R., & Sletto, B. I. (2009). *"We Drew What We Imagined" participatory mapping, performance, and the arts of landscape making.* Current anthropology, 50(4), 443-476.

Participatory mapping	
Cost	Requires a GIS expert and facilitator/moderator Cost depends on • GIS Software used, some freeware and trial versions available • Number of stakeholders/experts involved • Number of revision rounds→ depending on further use of the map • Level of detail (explanation provided for mapping process and area, number of unique map elements) • Complexity of elements being mapped (e.g. water cycles and pollution) • Frequency and extent of updates • Availability and cost of spatial data
Time required	Variable, as above
Repeatability	If done with two different groups of people, the maps will likely differ
Transparency	Potential to be highly transparent, depending on the process
Risk of bias	Medium. Relies on full and equal representation of all stakeholders
Scale (or level of detail)	Normally local
Capacity for participation	Highly inclusive. Local stakeholder participation is required
Data demand	Local-scale spatial data
Types of knowledge	All types of knowledge, but especially local knowledge (ILK)
Types of output	Map with legend and attributes (categorical or continuous variables) This could be part of a regional development plan and have an explanatory document
Specific expertise required	Expertise in GIS and facilitation of local stakeholders

Strengths	Weaknesses
Follows a clear protocol Engages local stakeholders and can combine scientific knowledge with indigenous and local knowledge Provides visual representation of data Can generate policy or management recommendations	Relies greatly on stakeholder knowledge (subjective) Can be biased, depending on facilitation and representativeness of stakeholders engaged

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21. Multi-Criteria Decision Analysis

Summary of method

Multi-Criteria Decision Analysis (MCDA) evaluates the performance of alternative courses of action with respect to criteria that capture the key dimensions of the decision-making problem, involving human judgment and preferences (Belton and Stewart 2002).

Key references

Belton V, Stewart TJ (2002). *Multiple criteria decision analysis: an integrated approach.* Kluwer, London. NOT OPEN ACCESS.

Greco, S., Figueira, J., & Ehrgott, M. (2005). *Multiple criteria decision analysis.* Springer's International series. NOT OPEN ACCESS.

Mendoza, G. A., & Martins, H. (2006). *Multi-criteria decision analysis in natural resource management: a critical review of methods and new modelling paradigms.* Forest ecology and management, 230(1), 1-22. NOT OPEN ACCESS.

Examples of application

Multi-criteria Decision Analysis was used to determine which of 60 or 70 environmentally important sites in or next to the Nature Reserve of Crau in Southern France reserve should be part of the reserve, and which areas could be released for development, such as for a gas pipeline scheme (Schmelev, 2010).

Spatial MCDA, incorporating GIS, was used to assess the risks and adaptive capacity of the Bach Ma National Park in Central Vietnam (Quynh Huong Nghiem, 2015).

Schwenk *et al.* (2012) combined MCDA with forest simulation modelling and scenarios (see Scenario Analysis above) to identify optimal forest management strategies in Vermont, USA.

Huang *et al.* (2011) provide an overview of environmental projects described in the published scientific literature that applied MCDA.

Huang, I. B., Keisler, J., & Linkov, I. (2011). *Multi-criteria decision analysis in environmental sciences: ten years of applications and trends.* Science of the total environment, 409(19), 3578-3594.

Quynh Huong Nghiem. (2015). *GIS-based Spatial Multi-criteria Analysis: A Vulnerability Assessment Model for the Protected Areas of Vietnam.* http://gispoint.de/fileadmin/user_upload/paper_gis_open/GI_Forum_2015/537558013.pdf

Schwenk, W. S., Donovan, T. M., Keeton, W. S., & Nunery, J. S. (2012). *Carbon storage, timber production, and biodiversity: comparing ecosystem services with multi-criteria decision analysis.* Ecological Applications, 22(5), 1612-1627.

Shmelev, S.E. (2010). *Multi-criteria Assessment of Ecosystems and Biodiversity: New Dimensions and Stakeholders in the South of France.* Queen Elizabeth House, University of Oxford. QEH Working Paper Series – QEHWPS181 (33 pages). The paper can be accessed at: http://www3.qeh.ox.ac.uk/pdf/qehwp/qehwps181.pdf

Multi-Criteria Decision Analysis	
Cost	Depends on • Expertise on decision software • The number of stakeholders/experts involved • Level of disagreement among criteria • Level of detail to and number of links and nodes • Good Facilitator/moderator to ensure transparency and inclusiveness • Scale of the problem and sectors, countries involved/addressed
Time required	Depends on the timescale for public consultations needed
Repeatability	Low. If you do it with two different groups (or individual experts if done individually), you get two different MCA
Transparency	High. Transparency is a crucial factor in MCA and can impact the acceptance of the criteria and the final decisions by the stakeholders involved
Risk of bias	Medium. Depends on representativeness of stakeholders/experts, whether individual input is incorporated or obtained in group discussion, and the quality of any data and predictive models incorporated
Scale (or level of detail)	Flexible. Can address detailed questions or broader problems
Capacity for participation	High. Relies on tacit knowledge and not as technical as Bayesian Belief Networks
Data demand	Depends on scale and sectors involved
Types of knowledge	Scientific, technical, opinion-based and indigenous and local. Tacit
Types of output	A matrix showing how different options perform on agreed criteria A report explaining the context and process
Specific expertise required	Usually requires expertise on decision analysis software For participatory creation of criteria you need skills in facilitation, forming the groups and familiar with the MCA methodology

Strengths	Weaknesses
Explicitly addresses trade-offs Suited for knowledge synthesis processes characterized by incomplete information Incorporates both quantitative and qualitative data, including scientific and local knowledge Combines information about the impacts of alternative courses of action with information about the relative importance of evaluation criteria for different stakeholders Deliberative-analytic methodology supports participatory processes and transparent decision making Can be combined with other knowledge synthesis methods (e.g. Systematic reviews, Delphi, focus groups)	Usually requires expertise on decision analysis software Possibly limited representativeness (only a small group of stakeholders usually involved) Some criteria such as cultural heritage or provisioning services vital for sustenance might not be amenable for trade-offs (though some MCA methods can also address these so-called lexicographic preferences) Allows manipulation if not used in a participatory and transparent way

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Appendix III: EKLIPSE Decision Support for selecting methods

10 questions for REQUESTER during dialogue, with fixed categorical answers used to filter appropriate methods. Methods appropriate to each answer are listed in an accompanying Excel file.

Question to requester	Options
1. Type of question	Seeking greater understanding or predictive power
	Scenario building to analyse future events
	Horizon scanning
	Seeking understanding of changes in time and space
	Seeking measures of anthropogenic impact
	Seeking measures of effectiveness of interventions
	Seeking appropriate methodologies
	Seeking optimal management
	Public opinion and/or perception
	Seeking peoples' understanding of an issue
2. What sources of knowledge should be included?	Scientific
	ILK
	Technical know-how
	Opinions and values
3. What types of information are useful or acceptable?	Financial information [economic]
	Qualitative data
	Quantitative data
4. Time available? When do you need the results?	Up to month
	2-4 Months
	4-8 months
	8 months - several years
5. Over what time horizon does the question recur?	Only relevant now, unlikely to recur. Will never need upgrading
	May recur in the future, at unpredictable times
	Definitely recurs, at predictable time intervals

Question to requester	Options
6. What financial resources are available (willingness to pay)?	High (full time mid-range salary for 8 months or more PLUS specialist expertise available) Medium (salary for 4-8 months) Low (less than four months salary)
7. What is the level of controversy?	Low controversy Controversy in the evidence Controversy in perception/values/opinion
8. What are the consequences of getting it wrong?	Low/limited consequences (e.g. doesn't impact on policy) Medium (e.g. a wrong policy/decision can be adapted/adjusted later Unacceptable (e.g. large economic/political/environmental costs)
9. What existing knowledge is the Network of Knowledge aware of?	Unknown Anecdotal/local/case studies/ information presented by stakeholders Data from surveys/monitoring etc. Research outputs that may be limited in scale/scope/relevance Relevant research outputs There is no documented existing knowledge
10. How narrow could the question get before it stops being policy-relevant?	Very broad (covers many possible responses or more than one policy area) Intermediate (Broader than a single well-defined response, ecosystem, but not across more than one policy area) Narrow (refers to a single well-defined response, ecosystem type or policy area)

4 questions for REQUESTER to understand the context. Specific methods can't be prescribed or filtered in response to fixed categorical answers, but EKLIPSE will provide guidance on how the answers influence the choice of method.

1. What are the expected outputs and outcomes?
2. What is the added value of this work to you?
3. What other sectors are affected/involved?
4. What types of ecosystem service are likely to be involved?

Knowledge Synthesis Methods

We identify 21 available Knowledge Synthesis Methods. Guidance notes are being developed for each of these (draft provided in Appendix II), describing the method and explaining its strengths and weaknesses, with key references and examples of use for policy decisions.

1. Systematic review
2. Solution Scanning
3. Summaries and Synopses
4. Meta-Analysis
5. Rapid Evidence Assessment
6. Scoping Review
7. Systematic Map
8. Vote-Counting
9. Non-Systematic Literature Reviews
10. Expert Consultation
11. Multiple Expert Consultation + Delphi
12. Causal Criteria Analysis
13. Bayesian Belief Networks (BBN)
14. Focus Groups
15. Discourse Analysis
16. Joint fact finding (JFF) and double sided critique (DSC)
17. Scenario Analysis
18. Structured Decision Making
19. Collaborative Adaptive Management
20. Participatory Mapping
21. Multi Criteria Decision Analysis (MCA/MCDA)

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