Defra Science Advisory Council - Social Science Expert Group (SSEG) Task Group

Report: Communicating Risk (November 2017)

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Executive summary and recommendations

To enable Defra to deliver an enhanced approach to communications a Task Group[1] of the Science Advisory Council's Social Science Expert Group was commissioned to consider, and advise on, risk communication across the spectrum of Defra's policy portfolio.

The Group focussed on research that enhances our knowledge of how risk is variously conceptualised and operationalised, and the principles and techniques for better risk communication. In doing so, the Group undertook to:

- Identify some major social science insights contributing to the development of approaches to understanding risk and, hence, to its communication. These include the importance of wider social, institutional and cultural factors influencing public understandings of risk (e.g. the social 'amplification' of risk); the uncertainties inherent in efforts to estimate and manage risk; and handling public dispute as a normal part of risk management in conditions of low public trust.

- Consider how to distinguish between different public constituencies and audiences so as to target risk communications more effectively. This includes the identification of the appropriate operational scale of risk management (and key partners) best placed to engage effectively in forms of two-way risk communication; four steps (and associated techniques) for undertaking 'two-way' communications; and a check-list matrix with which to frame and evaluate different communication objectives.

Recommendations

- Characterise public as well as expert understandings of risk first in order to make communications strategies more effective.

- Tailor risk communications carefully to target specific public constituencies, including 'informed' publics with direct experience of the risk concerned.

- Make the uncertainties associated with expert methods of risk estimation transparent in public risk communication. Where possible, codify the degrees of uncertainty attaching to specific claims.

- Use the full range of social science methods (and media) to engage the different forms of reasoning and behaviour that inform public understandings of risk, attending to the social contexts which shape them.

- Consider the potential value of Defra investment (with UK Research and Innovation (UKRI), GO-Science and/or The Government Social Research (GSR) in:

[1] Sarah Whatmore, Susan Owens, Steve Hinchliffe & Nick Pidgeon

- commissioning a systematic review of public engagement methodologies and compendium of sources of social science expertise in this field;
- piloting public engagement based risk communication activities in some of its Natural Capital Pioneer projects;
- developing a programme of internships / fellowships to evaluate techniques and design 'what works' protocols that progress Defra's risk communication capability.

Terms of reference

At its December 2016 meeting Defra SAC discussed the report of the National Flood Resilience Review (NFRR) and asked a sub-group of the SSEG to consider how the work on improving communication of flood risk might be taken forward. A scoping note was discussed at the SAC meeting in March 2017 and the Task Group asked to produce a short briefing paper, using the SSEG meeting in May to get input to a preliminary draft.

SAC guidance on the parameters for the briefing paper included:

- To look at risk communication across the *spectrum* of Defra's policy portfolio, attending to differences in types of hazard and degrees of uncertainty in the estimation of risk.
- To distinguish between complementary forms of risk communication - 'one-way' forms of *public information,* appropriate to emergency situations, and 'two-way' forms of *public engagement* appropriate to longer term risk management efforts. With a recently commissioned EA work task focusing on the former, the SSEG briefing should focus on the latter, less developed dimension of Defra risk communication practices.
- To focus recommendations on *practical actions for Defra* to enable the delivery of an enhanced communications approach, working with Defra's communications team and with input from other Defra customers.
- To inform and enable improved Defra capability, including the potential value of collaborative risk research / communications.

Defra participants at the May meeting of SSEG requested a workshop with Defra group stakeholders to input further to the paper. This took place in July and was well attended by social science and communications professionals across Defra group.[2] A number of short, illustrative case studies (on flooding; Anti-Microbial Resistance and hazardous substances) were presented and followed up with relevant Defra stakeholders to inform the final draft of the briefing paper presented at the meeting of SAC in September 2017.

[2] Defra Group attendees included Chief Social Researcher, Strategy Adviser - Strategy and Improvement Unit, Portfolio Manager - Marine and Fisheries, Deputy Director for Marine, Head of EU Exit Communications, Head of Strategy and Improvement, Head of Marine and Fisheries Portfolio and Transformation, Defra group Risk Lead, Portfolio Office and EU Strategy & Negotiations We are grateful to them for their valuable input.

Comments from SAC and Defra stakeholders have been incorporated into this final version.

Understanding risk

Ways of thinking about risk have evolved significantly over the past half century. In the 1970s, the dominant view was that the nature and magnitude of 'real' risks, and the costs and benefits associated with increasing or reducing them, could (and should) be determined by experts,[3] whose legitimacy and authority were little questioned. This paradigm, elements of which still prevail in some quarters, holds a particular, quantified expression of the likelihood and impact of a hazardous event to constitute the objective or 'real' risk and perspectives which deviate from this to be a product of erroneous (or irrational) 'risk perception'. In treating public perception of risk as something to be brought into line with 'real risk' as defined by experts, the paradigm can be said to embody a knowledge or information deficit model associated with a more general approach to the Public Understanding of Science.[4]

Over time, however, and informed by evidence from a variety of risk-related contexts, it became apparent that top-down information about 'real' or objective risk was not very effective in modifying public perceptions or behaviours, and could even be counterproductive, especially in the absence of any interrogation of the underlying variance between expert and public understandings of risk. In the past few decades, social science research across a range of disciplines has produced important new insights into the complex nature of risk, and its implications for more effective risk communication, in a context in which public trust in expert knowledge has to be earned and challenge is a routine part of risk management.

Public understandings of risk

Psychometric studies in social psychology were amongst the earliest to demonstrate that 'risk' is a multi-dimensional concept, and that responses to risk are influenced by numerous qualitative attributes of the risks concerned - whether, for example, they are familiar or novel, voluntary or imposed, routine or catastrophic, natural or artificial. Using principal components analysis to map different risks onto two axes - 'dread' (how much they are feared) and 'knowledge' (how well they are known) – they served to emphasise that these complexities could not be captured by simple numerical expressions or comparisons (see figure 1).[5] Moreover, the plotting of specific issues was shown to change over time and by location, as direct and mediated experiences of their effects develop and vary. For example, antibiotics may have migrated to the right on this diagram

[3] We take experts here to mean those professionally involved in the assessment of risk.
[4] See, for example, Bauer, 2009; Nowotny et al., 2002
[5] For example, Slovic 1987.

as growing evidence and recent campaigns raise awareness of the risks associated with the rise in anti-microbial resistance.

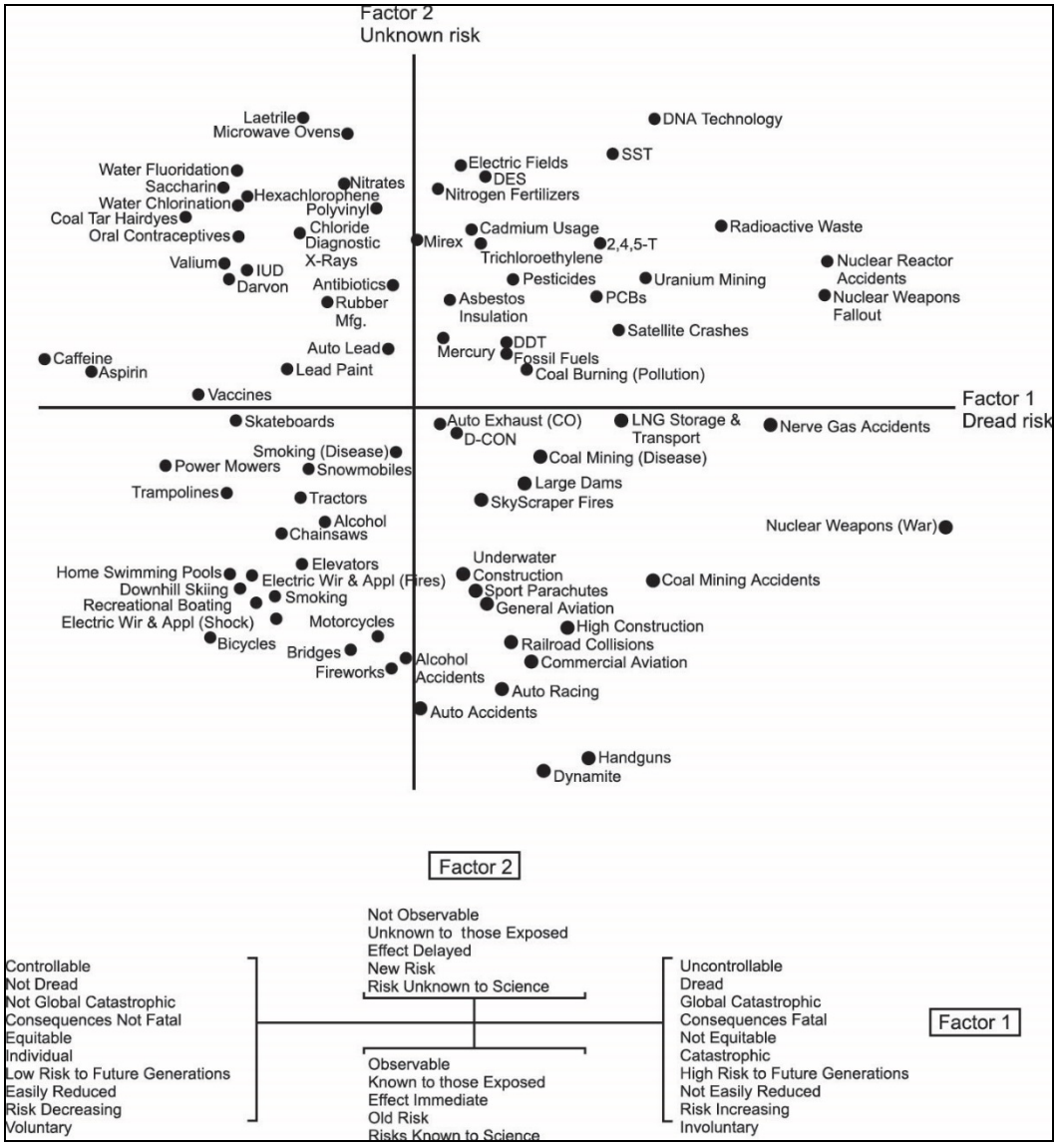

Figure 1: Perception of Risk (from Slovic, P. (1987). "Perception of Risk." Science 236: 280-285.)

Contemporaneous research in geography and environmental sociology showed how the communication of risk is mediated by the operation of complex institutional and social factors, such as the organisation of risk governance or inequalities in risk exposure, resulting in variation and change in how risk is understood — the so-called 'amplification' or 'attenuation' of risk.[6] These 'amplifications' include the processes by which some issues but not others come to be framed as matters of concern; the social and political contexts within which hazardous events take place; and the constitutive role of trust in the

[6] For example, Pidgeon et al., 2003; Pidgeon and Barnett, 2013

impartiality and competence of the institutions charged with anticipating, governing and managing risks.[7] Deploying different research methods and concepts, anthropological studies also provided insights into how societal responses to risk are conditioned by different cultural 'frames',[8] such as beliefs about the natural world or attitudes to technological change. Since provision of new information about risks cannot avoid being filtered through these cultural frames, such information is unlikely to lead to the changes in behaviours intended without taking account of what these frames are. These insights have been taken on board in some policy-making domains more effectively than others. For example, in the field of public health, the need to take account of public understandings of risks, whether for a general population or a particularly affected (target) constituency, and methods for doing so are relatively well developed.[9]

Acknowledging uncertainty

Adapting these anthropological research methods to new ends, scholars in Science and Technology Studies (STS) have more recently enhanced our understanding of risk by treating it as a particular case in the now widespread reliance of public policy-making on scientific expertise, and undertaking empirical investigation into the techniques (e.g. calculating statistical probabilities; modelling simulation), forms of evidence and professional conventions that underpin the expert estimation of risk.[10] These studies have helped to distinguish between risks that are well characterised, typically when events and their consequences have been observed repeatedly over time and modelled with reasonable assurance (e.g. flooding), and those that remain poorly understood because events are rare or have yet to occur and/or outcomes are highly uncertain or unknown (e.g. the environmental effects of novel and potentially hazardous substances).[11] A key concept emerging from this work is that of 'incertitude',[12] most commonly framed as the interplay between probability and uncertainty in terms of what can be known about risks and their impacts (see Figure 2). Further dimensions of incertitude include 'ambiguity' - when the nature of risks, or potential 'harms', are poorly characterised or disputed (e.g. BSE/vCJD),[13] 'indeterminacy', which acknowledges the inherent unpredictability of outcomes when human, technical, epistemological and environmental systems co-evolve (e.g. some long-run impacts of climate change);[14] and 'unknowability' or ignorance, which is not always reducible by further research and can be actively cultivated.[15]

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7 For example, Beck, 1992
8 For example, Douglas and Wildavsky 1982
9 For example, Horlick-Jones and Prades, 2009; Department of Health, 1998; WHO, 2007.
10 For example, Wynne, 1996; see discussion in Owens, 2015
11 The distinction is by no means a binary one, there are many gradations in between, but it has important implications for risk governance.
12 For example, Expert Group on Science and Government 2007; Stirling 2007; Spiegelhalter and Riesch, 2011.
13 See Hinchliffe, 2001.
14 Various typologies cover this ground differently. For Wynne (1992), for example, an important aspect of 'indeterminacy' includes the inappropriate transposition of empirical results from an experimental research setting (e.g. a laboratory) to an open or 'real world' setting.
15 See McGoey, 2012

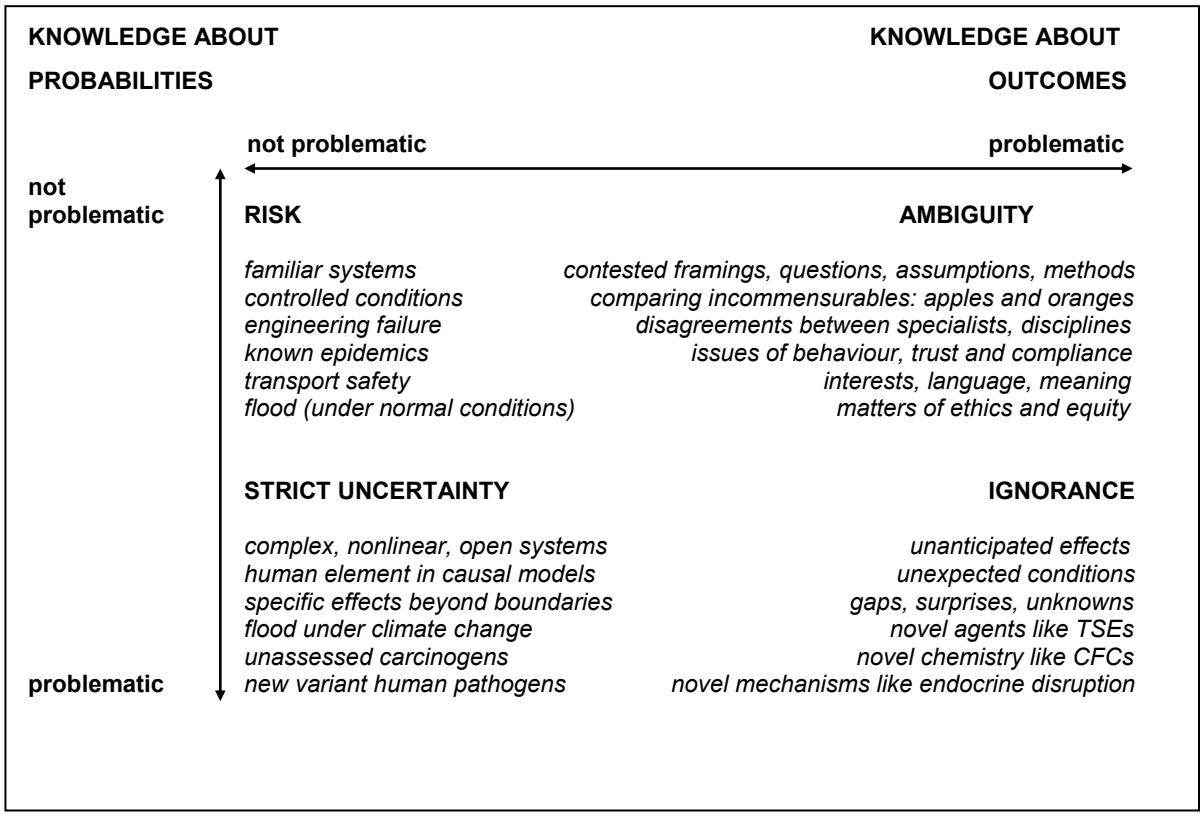

Figure 2: Contrasting states of incomplete knowledge, with schematic examples (from A. Stirling, Keep it complex, Nature 468, 1029–1031, 2010.)

These insights have informed practical improvements in risk communication in some policy domains from which others can learn. For example, the Intergovernmental Panel on Climate Change (IPCC) developed useful numerical and verbal codifications of the degrees of uncertainty and levels of confidence associated with its estimations of various complex risks, attaching these consistently to each of its key analytical claims.[16]

Handling risk disputation

Recasting 'risk' as a complex, multi-dimensional phenomenon complicates the familiar distinction between expert and non-expert (or 'lay') perspectives and judgements.[17] Expert assessments themselves involve subjective judgements as, for example, they are 'unavoidably influenced by the categories, presuppositions and models' of the assessors.[18] 'Lay' perspectives, on the other hand, are not necessarily misguided; they may be 'rationally based in judgements of the behaviour and trustworthiness of expert

[16] Interacademy Council 2010, Climate Change Assessments: Review of the Processes and Procedures of the IPCC <https://www.ipcc.ch/pdf/IAC_report/IAC%20Report.pdf>

[17] See, for example, Collins and Evans 2008.

[18] Shrader-Frechette 1995: 118

institutions'[19] (including lack of transparency in risk estimation), or otherwise informed by direct experience of hazardous events. People in localities vulnerable to flooding, for example, are more likely to frame risk not only in terms of physical processes but also with regard to the reliability of institutions responsible for land and river management and flood protection.[20] Or, to take the example of fracking, if the likelihood of harm from induced seismicity or well failure is judged to be small in 'well regulated facilities',[21] then trust that facilities will be well regulated in practice is crucial to the assessment of risk. In short, public understandings of risk incorporate the possibilities that regulation might be inadequate or planning and protective measures might fail.[22]

To complicate things further, risk management controversies commonly involve civil society coalitions of professionals, concerned publics and stakeholder groups with different interests, problem framings and knowledge bases, and engaged in the production of competing assessments of risk.[23] In this context, the routine reliance on science to resolve issues for which "facts [are] uncertain, values in dispute, stakes high and decisions urgent" presents new challenges for the articulation between 'expertise' and 'policy-making' characterised by Funtowicz and Ravetz (1985) as 'post-normal science' (see figure 3)

In consequence, this work variously argues for a greater role for plural methods of public engagement in the conduct of risk communication to foster more deliberative risk management opportunities in conditions of low trust, particularly when the political and economic stakes are high and/or there is a great deal of incertitude.[24]

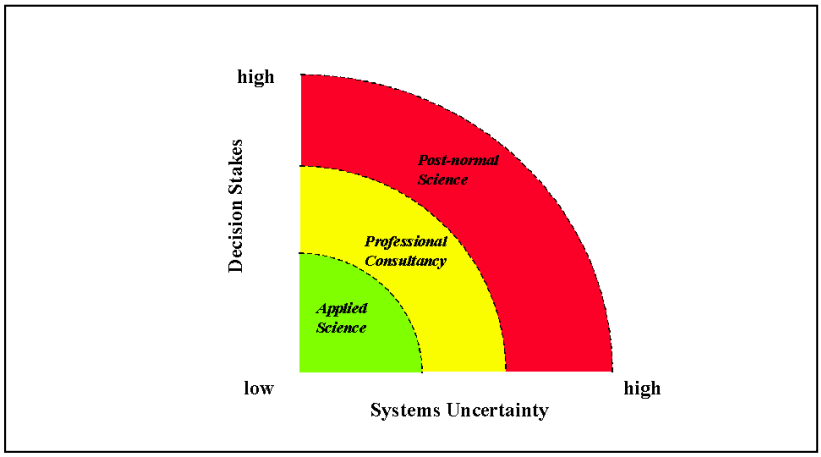

Figure 3: Post normal science (from Funtowicz, S. and Ravetz, J. (1985). Three kinds of risk assessment: A methodological analysis. In: Risk Analysis in the Private Sector. Editors: C. Whipple and V. Covello. Plenum Press, New York

[19] Wynne 1996: 57. See also Chilvers, 2007
[20] See Whatmore and Landstrom, 2011.
[21] See Royal Society and Royal Society of Engineering, 2012.
[22] Such possibilities are well-documented in studies of how complex organisational failures come about in technical system (see, for example, Turner & Pidgeon, 1997; Perrow, 1984)
[23] For example, Sabatier, 1987; Hajer, 1995.
[24] See, for example, Funtowicz and Ravetz, 1985; Hagendijk and Irwin, 2006; Stirling 2007.

None of this research should be taken to suggest that risk-related expertise can be dispensed with (clearly, it remains essential); nor that because risks can be shown in important senses to be socially conditioned this makes them any less 'real'. Precisely because one of the duties and expectations of governments today is to protect against the hazardous events, technologies, foods, pollutants etc. that threaten the wellbeing of people and/or the environment, insights from the social sciences have important contributions to make in improving the effectiveness of risk governance. Such insights, into the public understandings of risk, the uncertainties associated with risk estimation, and the normalcy today of risk management controversies, have already had some influence in risk governance in some quarters.[25] It would be mistaken, however, to assume or imply any simple progression from top-down, technocratic to more open, deliberative approaches to risk communication. The current situation might best be characterised as one in which different (but partially overlapping) risk paradigms co-exist, sometimes uncomfortably. In this context, a pragmatic approach to improving the effectiveness of risk communication is to distinguish between two complementary modes - 'one-way' modes of *public information*, appropriate to providing clear instruction in 'emergency' situations and 'two-way' modes of *public engagement* appropriate to the equally vital task of building public trust in risk management decision-making longer term.[26] The final section focuses on the latter mode and draws out some key lessons for effective 'two-way' risk communications in principle and in practice.

Lessons and tactics for better risk communication

The National Flood Resilience Review[27] published in September 2016 identified eight components of good risk communication practice in the case of flood risk management, which provide a useful starting point for general lessons about public communications best practice relevant across the spectrum of Defra group risk management challenges.

[25] These three themes echo those highlighted by Kasperson (2014) in his evaluation of what has been learnt from successes and failures in public health risk communication over the last 30 years.

[26] For examples of Defra relevant applications of these arguments, see Lord Phillips' report on BSE (2000), Lane et al., 2011; Crowley et al., 2017

[27] https://www.gov.uk/government/publications/national-flood-resilience-review. Sarah Whatmore and Susan Owens were members of the Review's Science Advisory Group, as were Charles Godfray (Chair of Defra SAC) and Ian Boyd (Defra CSA)

1. Think carefully about the audience for any communication and do not address 'the public' as an undifferentiated aggregate of individuals
2. Avoid implying that target audiences are ignorant and simply require 'education'
3. Make data informing risk estimations public and, where possible, involve them in data collection through 'citizen science' opportunities
4. Provide an early explanation of the logic and structure of the central tenets and argument of any communication
5. Don't over-claim
6. Express estimations of the likelihood of events in intuitive, consistent and unambiguous ways
7. Make assumptions, uncertainties and levels of confidence in the estimations transparent
8. Take particular care with specialist terminologies that include words with a different meaning in everyday parlance

Two-way, or *public engagement*, modes of risk communication are argued to contribute to embedding these principles into practice in three ways, characterized as normative, substantive and instrumental.[28] The *normative* argument stresses that dialogue is a good thing in and of itself in a democratic society; the *substantive* argument is that dialogue will help to generate new insights for better quality outcomes by opening up the framing and evaluation of risk management decisions and options, particularly where risks are novel, ill-defined or ambiguous; and finally the *instrumental* argument is that dialogue may increase the legitimacy of decisions, and by so doing foster greater public trust in risk estimation expertise and management agencies.[29] As a counterweight to the 'knowledge deficit' model of the public understanding of risk that informs one-way or instructive modes of communication, public engagement approaches are designed to facilitate an exchange of perspectives, insights and information between expert risk management agencies, other interested groups, and people knowingly and unknowingly living with risk in particular social contexts.[30] This requires a good grasp of the landscape of public understandings of

[28] See, Fiorino, 1990.
[29] Lord Phillips report of the Inquiry into BSE/vCJD in the UK, 2000 - webarchive.nationalarchives.gov.uk/20060715141954/bseinquiry.gov.uk/
[30] For useful reviews of the principles and practices of public engagement see Wilsdon and Willis, 2004; UK Resilience (n.d.)

risk as well as expert risk estimation and assessment (and the uncertainties that attach) if effective communication between the two, and in both directions, is to be achieved. An associated organisational challenge for such approaches is how to handle the different spatial scales and time horizons on which risk is calculated by experts and experienced by people.

Four steps in a two-way risk communications strategy

In working through this risk management process, in which communication is embedded, it is useful to divide the process into four interactive tasks: characterising risks, and characterising disputes associated with risk management issues, identifying and evaluating communication aims and methods, identifying 'informed' publics.

Step 1: Characterise the risk

Characterisations of risk against the axes of 'dread' and 'knowledge' illustrated in Figure 1 above, points to four common dimensions of variation in public understandings of risk that can usefully inform a two-way or public engagement communications strategy by helping to identify and target the salient public concerns for the risk management issue in question. These include: *fearfulness* - the degree of anxiety attached to different dimensions of risk;[31] *knowability* - the extent to which risks are known, directly observed or experienced; *tractability* - the degree to which risks are amenable to being, and likely to be, fixed; and *legitimacy* - the extent to which the relevant expert risk management regime is trusted.

Just as the plotting of specific issues has been shown to change over time and by location as understandings of their effects develop and vary (see above), so risk communication strategies can use this to identify and effect shifts that make a risk more manageable.

Step 2: Characterise any controversies

Disagreements are a normal aspect of effective risk management today. Any communications strategy is strengthened by some understanding of the landscape of disagreements associated with the risk management issue it seeks to address. For target audiences at different scales (e.g. local or national), it is desirable to have at least an indicative map of *what* is at issue; *who* is engaged and whether any interest coalitions have formed; and the key historical or contextual factors that help explain *how* or *why* the

[31] The Department of Health 'pointers' report (1998) lists eleven aspects of risk in order of the degree to which they induce public anxiety. The top five are - involuntary risks; inequitable risk exposure; inescapable risks; unfamiliar risks; and un-natural (anthropogenic) risks.

issue came to be contentious. Several bodies of research provide approaches and tools for characterising risk controversies and disputes of relevance to Defra. These include work on conflict resolution that seeks to manage disagreements at the extremes when they can lead to polarisation, escalation and conflict,[32] and work on mapping controversies that uses digital 'issue-crawler' techniques to harvest social media and produce an 'issue map' of the key nodes and interest coalitions engaged in a dispute[33] and work on democratising environmental sensing technologies for citizen engagement.[34]

Step 3: Specify communication aims and methods

Two-way or public engagement modes of risk communication can be useful in addressing several different risk communication functions. In designing any communication strategy, it is important to be clear from the outset about the aim of the exercise, the most appropriate approach and methods, and the indicators of success against which its effectiveness can be evaluated. To illustrate, Table 1 provides a check-list of key considerations that might inform the design of three types of risk communications strategy aimed respectively at increasing risk awareness, changing risk behaviours, and shifting risk management practices.

[32] The so-called 'conflict-curve' (see Swanström and Weissmann, 2005). For a Defra relevant case see (Crowley, et al. 2017) on invasive species management.

[33] For a review see Marres and Moats, 2015. Controversy mapping tools and case studies (many Defra relevant) can be found at the MACOSPOL website - www.mappingcontroversies.net/

[34] See the air pollution public engagement initiative led by Jennifer Gabrys on *Investigating Environmental Sensing Technologies and Citizen Engagement* at **citizensense.net**

Table 1 Checklist for framing and evaluating different risk communication tasks

What is to be achieved?	*Success looks like*	*Key issues*	*Relevant Social science methods*	*Mode of address*
Risk awareness	• *Informed citizenry (satisfying a right to know function)* • *Attitudinal change* • *Improved response to threat* • *Greater legitimacy for addressing threat* • *De-escalation/ assurance of over-inflated threat*[35] • *Better risk prevention and preparedness* • *Greater involvement and participation in risk assessment and management*	• *Competing accounts of risks/ surfeit of risk messages* • *Requires knowledge of lived experience in order to understand how people make sense of risk* • *Socio-economic and cultural diversity (gender, age, income, available time, social relations, race, location etc.)* • *Complex risk landscape (people weigh up different risks e.g. evacuation carries risks of looting loss of property)* • *Uncertainties and indeterminacies around for example safe levels, thresholds, temporality of effects* • *Current culture*[i] *of garnering attention through fear/ danger/ emergency* • *Message fatigue, related to surfeit and false positives and negatives undermining trust/ attention.* • *Current scepticism and cynicism in relation to science, authority and government.* • *Ignorance*[ii] *not always passive, but an active response to surfeit. More messaging makes more ignorance* • *Responsibility and blame attribution may undermine simple messaging*	• *Focus groups* • *Social media data analytics* • *Social marketing methods for identifying key publics* • *Q method as means to identify key groupings and patterned subjectivities* • *Controversy mapping (digital)* • *Deliberative mapping*	• *Education and consultation with relevant and diverse social groups* • *Multi-platform media strategy* • *Identification of key knowledge brokers, message amplifiers, boosters, aggregators, cascading nodes, trusted intermediaries*[iii] *(see step 3 and figure)* • *Identification of relevant languages for communication (numbers, probabilities, text, images, symbols, cultural values).*
Capacity for change	• *Clear pathways to, and support for, change* • *Uptake of preventative practices, or more responsive behaviours* • *Better prevention, risk anticipation, capacity and resilience*	• *Change involves understanding motivations & capacities, social & environmental contexts* • *Risk inequalities – the most vulnerable often least able to change* • *Contextualise risk behaviour in relevant social contexts (friends, families etc) e.g. risk tolerance from baby food different to that from personal alcohol consumption* • *Organisational change has its own dynamics* • *Where issues involve a number of organisations (including inter-agency issues) then coordination is key* • *Competing economic and other interests need to be understood* • *Conflict and disputes offer levers and barriers to change*	• *Competency Groups* • *In situ workshops* • *Community modelling* • *Targeting resources to most vulnerable* • *Developing pioneer communities followed by work on translating experiences between settings*	• *Coproduction of pathways to change* • *Co-Identification of key change agents, drivers and structural barriers to change* • *Identification of most vulnerable* • *Modelling of interventions and possible unintended consequences of actions*
Long term shifts in practice	• *Relevant issue publics* • *Cultural change (new norms)* • *Resilience* • *Public mandate for change*	• *Prevalence of unintended consequences, especially for single issues.* • *Changing evidence base and frameworks can lead to changing priorities* • *Counter-science and active use of uncertainty to reduce effective change* • *Changeability of hazards– eg phenotypic and genotype plasticity of bacteria.*	• *Competency Groups (Science/public collaborations)* • *Scenario development and horizon scanning* • *Deliberative mapping* • *Community modelling*	• *Iterative process of generating and monitoring shifts in values and practice* • *Clear responses to changing priorities*

[35] It is worth noting, however, that almost every threat to the environment or human health is regarded by interested person or group as 'over-inflated'. See, for example, the EEA report, 2002.

Step 4. Identify informed publics / stakeholders

There is clear evidence that greater experience of flood risk leads to better informed and engaged public constituencies, both in relation to awareness of risk and preparedness to take action.[36] This and other risks with similar characteristics of frequency, familiarity, and robust expert knowledge, represent risk management issues where two-way risk communication involving public engagement methods is likely to be of particular benefit both in terms of improving risk estimation at a scale meaningful to those living with the risk and of improving public trust in risk management agencies. To achieve this requires the differentiation of relevant groups and tailoring of risk communications appropriately. In the case of stakeholder groups, social media data analytics[37] can be used to plot stakeholders against two axes – *influence* (how well connected they are in their local or professional communities) and *interest* (how motivated are they by the risk management issue).[38] This approach enables a sub-group of stakeholders to be targeted within, say, a practitioner community like farmers, whose experience and influence within that community make them potential allies in communications strategies that seek to change community behavior, in relation, say to risk management of water quality or veterinary antibiotic use. Harnessing such so-called 'pioneer practitioners' as allies in risk management communication has been shown to have beneficial effects in changing risk perceptions and behaviours in the larger group.[39]

Alternatively, more intensive research methods that bring publics constituted by dint of their shared experience of living with risk into collaboration with scientists and/or policy makers involved in risk estimation and management can be effective in identifying and engaging 'informed publics' who have the capacity to influence others in their local community (and other similarly risk affected communities). These methods include participatory and community modelling exercises, deliberative mapping techniques and competency groups, and have contributed to several studies relevant to Defra risk management concerns, including flood and drought risk, environmental contamination and radioactive waste.[40]

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[36] For example, Burningham et al., 2008; Bradford et al., 2012; Demski et al., 2017
[37] See Tinati et al., 2014 for some of the challenges associated with these methods
[38] For example, UK Resilience, n.d.
[39] For example, Crowley et al, 2017
[40] For competency groups see www.environmentalcompetencygroups.org/ ; for participatory modelling see Voinov and Brown Gaddis, 2008 and community modelling see www.communitymodelling.org, and for deliberative mapping see Chilvers, 2007.

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