

1 **Scientific commentary**

2
3 **Strategic analysis of environmental policy risks – heat maps, risk futures**
4 **and the character of environmental harm**

5 G Prpich, J Dagonneau, SA Rocks, F Lickorish and SJT Pollard*

6
7 *Cranfield University, Centre for Environmental Risks and Futures, Environmental Science*
8 *and Technology Department, School of Applied Sciences, Bedfordshire, MK43 0AL, UK*

9 *corresponding author: Tel: +44(0)1234 754101; Email: s.pollard@cranfield.ac.uk

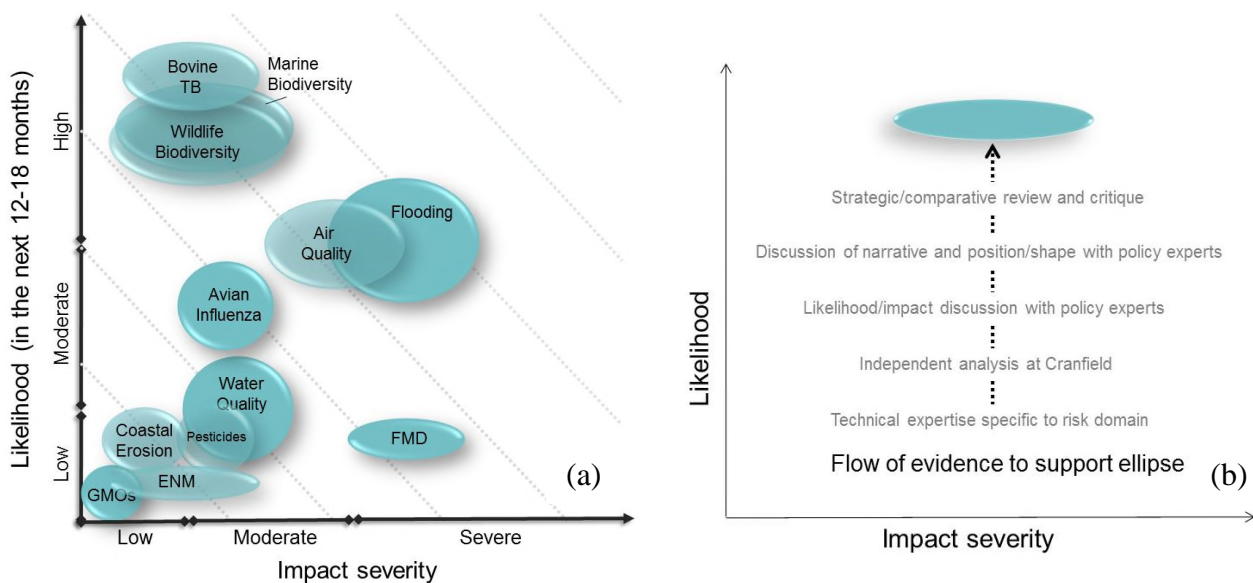
10
11 **Abstract.** We summarise our recent efforts on the policy level risk appraisal of
12 environmental risks. These have necessitated working closely with policy teams and a
13 requirement to maintain crisp and accessible messages for policy audiences. Our
14 comparative analysis uses heat maps, supplemented with risk narratives, and employs the
15 multidimensional character of risks to inform debates on the management of current residual
16 risk and future threats. The policy research and ensuing analysis raises core issues about how
17 comparative risk analyses are used by policy audiences, their validation and future
18 developments that are discussed in the commentary below.

19
20 **Keywords:** policy, risk, strategic, analysis, environmental, comparative, futures

21
22 **The policy level analysis of environmental risk.** The strategic appraisal of
23 environmental risks within government is increasingly influential in informing debates on
24 investment priorities, evidence-gathering and resource allocation. Strategic risk analysis in
25 this sense refers to the high-level analysis of environmental risks captured within a policy
26 domain. Researchers in this field encounter a number of questions posed of policy level risk
27 analysis: how should governments appraise the broad fields of public risk that they share
28 responsibility for with others?; what confidence do we place on the high-level analysis of
29 policy risks given the inherent uncertainties?; how should we evaluate the future magnitude
30 of extant risks and the significance of risks on the far horizon?; and do visualisations of risk,
31 made crisp and accessible for policy makers, help or hinder debates on risk policy? Our
32 investigations have caused us to rethink accepted principles of risk analytics and metrics *a*
33 *priori*, and exposed tensions of interest to a wider policy audience.

1 For decision makers, comparing risks and opportunities and then acting on this
 2 analysis, is a necessary feature of their role (Defra, 2011). What distinguishes one risk, or
 3 opportunity, from another is its character (Klinke and Renn, 2002; Sparrow, 2008); not only
 4 its magnitude, dimensions (of likelihood, consequence and uncertainty) and significance; but
 5 also the means by which it might be realised, how likely it is to come to fruition (or not), the
 6 individual mechanisms by which this might occur, the knock-on consequences that may
 7 emerge, and how it is understood and managed by those that engage with it (Pollard *et al.*,
 8 2004). Researchers have referred to the attributes of character that a risk may possess
 9 including latency (delayed onset of harm), reversibility (of damage), the stock at risk (the
 10 number or value of receptors to which harm is posed; Environment Agency, 2005)
 11 Frameworks for analysing strategic risks also exist that seek to represent the
 12 multidimensional features of environmental risks using analytic, schematic and narrative
 13 forms for policy makers so they can be meaningfully compared (US Environmental
 14 Protection Agency, 1987; Morgan *et al.*, 2001; Klinke and Renn, 2002; Andrews *et al.*, 2002;
 15 Pollard *et al.*, 2004; Environment Agency 2002; 2005). Our adaption of Klinke and Renn's
 16 (2002) risk characterisation for the German Council on Global Change (1998; Prpich *et al.*,
 17 2011), which has seen limited application in England and Wales, allows for the positioning of
 18 multiple strategic policy risks, appraised in the short term (Jan 2012), on to a single risk 'heat
 19 map' (Fig. 1a; Science Advisory Council, 2012).

20



23

24 Figure 1(a,b). An illustrative appraisal of 12 strategic environmental risks for Defra (Science
 25 Advisory Council, 2012) employing Prpich *et al.* (2011). Ellipses reflect the relative

1 magnitude and 2-dimensional uncertainty in likelihood and consequence for residual policy
2 risks, assessed over a 12-18 month horizon (from Autumn 2011) assuming existing risk
3 management measures in place. Their positions are informed through a flow of supporting
4 evidence, independent analysis and deliberative process (Fig. 1(b)). Key: GMOs genetically
5 modified organisms; Bovine TB (tuberculosis); ENM engineered nanomaterials; FMD foot
6 and mouth disease.

7

8 **Using ‘heat maps’ to inform discussions on environmental risk management.**

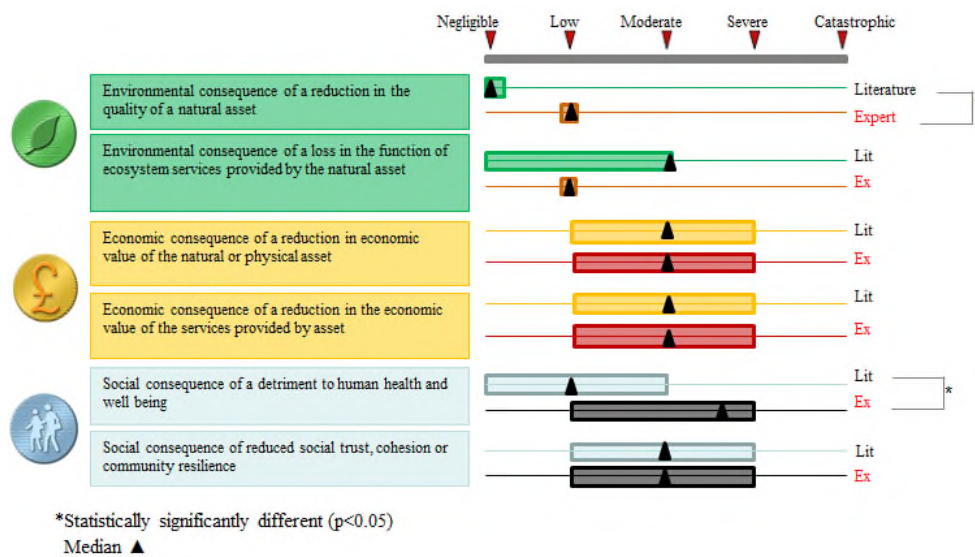
9 Schematics are useful tools for communicating risk and widely used in corporate (Willis *et*
10 *al.*, 2004; 2010), political (e.g. Cabinet Office, 2010; 2012; World Economic Forum, 2011)
11 and public spheres (Spiegelhalter *et al.*, 2011) to inform debates on strategic decision-making
12 under time limited constraints. Visuals like Fig. 1(a), which embody a suite of individual
13 risks, cannot be precise because each ellipse (in this case) embodies a range of impacts and
14 uncertainties. There is a vibrant debate about the utility of risk heat maps in the practitioner
15 literature and one must guard against their use in isolation of, or in substitute for, other risk
16 analyses that exist in parallel; say, for example, the nationally-significant ‘import risk
17 assessments’ that evaluate the risks of animal disease incursions across national borders. The
18 debates on strategic risk appraisal can be condensed into a discussion on whether concise
19 visualisations help decision-makers or not, given the complexity of policy-level risk.
20 Pragmatists usually argue for the value of these analyses, accepting a degree of
21 methodological compromise, so to inform discussions on risk comparisons and risk
22 management strategies. A more purist view seeks a complete analytical risk characterisation,
23 but can fall foul of the varying degrees of data quality, much of which is poor resolved, in
24 spatial or temporal terms, at the policy level because it represents an overarching national
25 policy picture. Seeking to straddle these positions, we have supported our visuals (Fig.1 (a))
26 with a narrative on the character of the risk and current risk management strategy (Prpich *et*
27 *al.*, 2011). At best, each ellipse (frequently reduced to a deterministic point in many
28 analyses) indicates a central tendency (position, dimensions) for the set of risks it represents.
29 The presentational challenge is to reconcile the complexity of these policy-level analyses, as
30 informed by a hierarchy of analysis and discussions (Fig. 1(b)), with a utility of application
31 for policy audiences, for the purpose of discussing current and future risk management
32 strategies (Government Office for Science, 2011). For example, risks within the air quality
33 policy domain (Fig. 1) may be episodic or on-going; their harms immediate or latent. The
34 practical need is to assemble the complexity of these issues into a single policy area and

1 assess them as one, over a designated time frame. A common question asked of policy
2 makers when considering residual risk, that is the risk that remains with existing management
3 measures in place, is – how likely is this policy area to ‘flare up’ (through a manifestation of
4 residual risk) over the next 12-18 months, and what impact may this have, given the risk
5 management measures in place? These assessments embody considerable and some
6 unresolvable uncertainties, but expert judgement can be made accepting this, rather than
7 holding out for an analysis of the discrete probabilities and consequences that might arise
8 from any set of events and unknowns (Government Office for Science, 2011). Complete
9 confidence cannot be guaranteed, but a meaningful judgement can be made on which to base
10 future risk management decisions.

11 Decision makers desire a structured and supportable basis for acting on the risks
12 posed by a policy area over a given future. At this level, a quantitative assessment of the
13 likelihoods of all possible events, processes and trends captured within a policy area over a
14 12-18 month period is not possible, because not all events can be assessed and aggregated
15 completely, nor fairly. More value may be had in employing a semi-structured, heuristic
16 approach that is fit for purpose and resource efficient in decision terms. This type of
17 framework (Prpich *et al.*, 2011) relies on experts synthesising a large body of evidence and
18 then arriving at a summary characterisation of risks for a policy domain, which can be then
19 compared with other risks across a policy portfolio, accepting the compromises required.
20 Critically, this approach becomes a means for the organisation to debate on-going or
21 emerging risks with their Board, along with a discussion of the effectiveness of current
22 management strategies and future management actions. To be useful, this discussion must
23 focus on risks that are, or are not, manifest; and those risks that are, or are not, appropriately
24 managed by reference to their extent and character. Trading off the relaxation of controls in
25 one risk area with the tightening of interventions elsewhere, are a component of these debates
26 and open up the prospect of seizing opportunities (for resource allocation, for targeted
27 evidence gathering) in resource-constrained times.

28 Assessing policy risks requires a compromise in how likelihood is considered. An
29 event-based definition of likelihood, in isolation, will not provide the differentiation that
30 decision makers require to understand the risks within their policy portfolios; risks that also
31 have exposure likelihoods, and likelihoods of harm in the event of exposure, for example.
32 Apart from floods, and possibly animal disease incursions, the data for other policy areas (at
33 least for England and Wales) is insufficient at a policy level to support a sophisticated risk
34 analysis. Our attempts to reconcile issues of data paucity and presentational clarity by

1 employing the elicited views of technical policy experts holding specialist domain expertise
 2 have compared well against an *a priori* evidence-based analysis using the open literature
 3 (Fig. 2, for foot and mouth disease risks). Notwithstanding that environmental impacts and
 4 consequences are difficult to predict and manage, the analysis in Fig. 2 suggests the analysis
 5 of consequences for foot and mouth disease risks based on expert opinion is reasonably well
 6 calibrated with the literature.



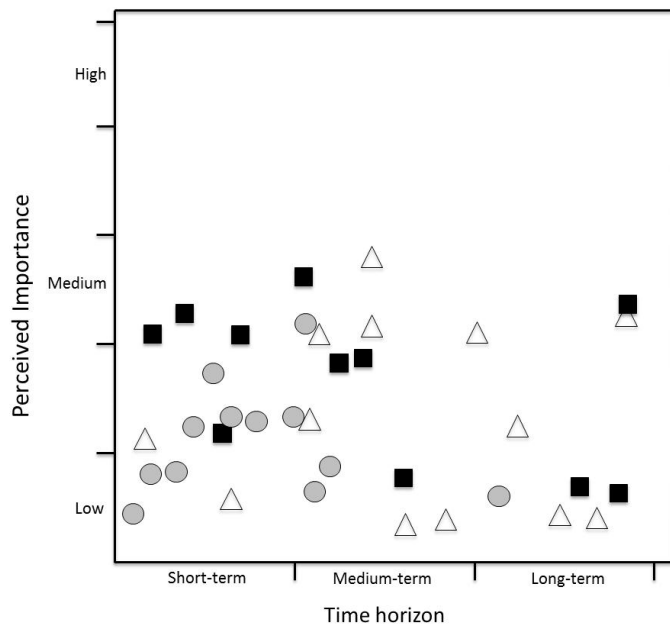
7
 8 Figure 2. Policy expert vs. literature-informed estimation of consequences (n=6) from foot
 9 and mouth disease risks, across environmental (leaf), economic (£) and social (people)
 10 consequence categories (2 attributes in each consequence category).

11
 12 **The evolution of future risks.** Strategic risk analyses rely on experts to synthesise
 13 knowledge about certain ‘high level’ risks and make intelligent judgements on how these
 14 risks may evolve forward in time over years and decades. The further forward in time, the
 15 more challenging it becomes to define and assess the likelihood of consequences being
 16 realised. Policy makers may resort to risk ranking exercises that ask experts how they
 17 perceive the future level of risk posed by a current issue. Global analyses of perceived
 18 threats to the world economy exist, for example (Ernst and Young, 2010; World Economic
 19 Forum, 2011; Lloyds, 2013). Notwithstanding the debates on method (see Andrews 2004;
 20 House of Commons, 2011), one cannot argue with the impact these have in shaping policy
 21 discussions about (i) the effectiveness of existing risk management measures; (ii) our appetite
 22 of the current level of residual risk; (iii) our understanding of how these risks might evolve
 23 moving forward; and (iv) how prepared we are for these risk ‘futures’.

1 Policy makers and business leaders (Willows and Connell, 2003; Economist
2 Intelligence Unit, 2011) are increasingly interested in the longer term evolution of risk – both
3 how extant risks may develop in position, magnitude and character, together with their
4 attending uncertainty over time (Fig.1); and in new emergent risks that may appear on the
5 horizon (International Risk Governance Council, 2011). What can we confidently say about
6 these risk futures to guide the policy response in the present that will ensure a ‘no regrets’
7 policy design? One approach to the evolution of current risk, is to elicit policy officials’
8 views on the likely, optimistic and pessimistic scenarios for the evolution of risk (size, shape,
9 position for Figure 1) over time, though this raises the additional challenge of representing
10 risk evidence of elusive strength and weight at the distant horizon, let alone the variance in
11 weight of evidence between policy risks (not represented, readers should note, in Fig. 1).

12 For emergent risks, exploratory horizon scanning and risk characterisation is required.
13 Techniques for structured risk characterisation (significance, uncertainty) are in their infancy
14 when applied to mid- to long-term risks. It is clear that technical risk analysis alone will be
15 insufficient, because how we respond now to emergent risks in the near term will alter their
16 character as they come into focus. A growing appreciation of the organisational, political and
17 social dimensions of emergent risks (International Risk Governance Council, 2010; 2011) is
18 forcing a reappraisal of the features of socio-political systems that offer fertile ground for
19 emergent risks to gain traction. Our own categorisation of risk insights to inform policy
20 discussions, that is emerging from a structured programme of horizon scanning for the
21 environment ministry in England (Department for Environment, Food and Rural Affairs; Fig.
22 3), presents the importance of risks to the strategic objectives of an organisation over various
23 time horizons – again – as one input to risk management and policy design.

24



1
 2 Figure 3. Illustrative categorisation of 36 risks after 9 months' horizon scanning. Symbols
 3 denote individual risks, with dominating ■ environmental; △ economic; and ● social risk
 4 attributes, evaluated by importance to policy stakeholders over 1-3 (short), 4-10 (medium)
 5 and 10+ (long) year time horizons. An emerging risk with dominant economic features might
 6 be the adulteration of meat products for human consumption; with dominant environmental
 7 features, the future overuse of water resources; with dominant social features, the detrimental
 8 impact of increased international demand for traditional crops such as Quinoa on local
 9 populations.

10
 11 **Progressing the agenda.** Understanding policy level risk is a normative process
 12 involving easily quantifiable and not easily (or not confidently) quantifiable aspects.
 13 Decisions on risk management involve societal judgements, with their inherent bias, and
 14 necessitates integrating numerous lines of evidence and uncertainties inherent to risk
 15 management policy, including the question of non-action - what would happen in the
 16 immediate and far future if we did nothing now? Policy managers must integrate the weight
 17 of this evidence, the attending uncertainties and degree of precaution deemed appropriate
 18 when undertaking risk policy analyses. These visual representations of policy level risk
 19 discussed here are one contribution to this set of considerations. The schematics used diverge
 20 substantially from the probability distributions around expectation values of risk, which are
 21 the conventional preserve of quantitative exposure assessors, for example. They are
 22 admittedly controversial in the literature and in practice (e.g. see discussion in House of
 23 Commons, 2011) because they raise fundamental questions about risk, uncertainty and the

1 representation of complex multidimensional risks in what might appear to be naïve schema.
2 We do not suggest postponing a better quantification of individual risks that aggregate into
3 policy level issues and recognise the need for precaution for risks that embody large
4 unresolvable uncertainties. Equally however, we argue not to lose sight of the inherent value
5 of risk analysis which is to evaluate the significance of risk and promote debate on the
6 suitability of risk management strategies, including whether they require amendment in light
7 of new knowledge about the changing character of risk. To aid debates on the management
8 of policy risk, we believe it essential to support these types of visualisations with
9 accompanying narratives on risk character, risk management strategy and statements of
10 accountability for risk management, as discussed in Prpich *et al.* (2011). This will continue
11 to draw in the organisational, technical and social dimensions of how we elect to manage
12 risk, and enliven the debate on shared accountabilities for public risk management, including
13 among the wider citizenry, as we engage on the intergenerational issues that are raised by
14 thinking decades ahead (Perhac, 1998; Foot, 2009; Risk and Regulation Advisory Council,
15 2009; Beddington, 2013).

16

17 **Acknowledgements.** This research was co-funded by Defra, EPSRC, NERC and ESRC
18 (EP/G022682/1) under a strategic grant to Cranfield University. FL's contribution is part-
19 funded through a Defra grant (SD0339) to Cranfield University. The opinions expressed in
20 this commentary are the authors' alone.

21

22 **References**

- 23 Andrews C.J. *Lessons from the New Jersey Comparative Risk Project.* In: Linkov, I. and
24 Ramadan, A.B. (eds.) (2004) *Comparative risk assessment and environmental decision-*
25 *making*, Proceedings of the NATO Advanced Research Workshop, held in Rome
26 (Anzio), Italy, October 13-16, 2002, Kluwer Academic Publishers, Dordrecht,
27 Netherlands; 2002.
- 28 Beddington, J. Addressing the challenges of the 21st century. *FST Journal* 2013: 21(1); 4-7.
- 29 Cabinet Office. *National risk register of civil emergencies.* Cabinet Office, London, UK;
30 2010. Available at: [http://www.cabinetoffice.gov.uk/media/348986/nationalriskregister-](http://www.cabinetoffice.gov.uk/media/348986/nationalriskregister-2010.pdf)
31 [2010.pdf](http://www.cabinetoffice.gov.uk/media/348986/nationalriskregister-2010.pdf).
- 32 Cabinet Office. *National risk register of civil emergencies.* Cabinet Office, London, UK;
33 2012. Available at: [https://www.gov.uk/government/publications/national-risk-](https://www.gov.uk/government/publications/national-risk-register-of-civil-emergencies)
34 [register-of-civil-emergencies](https://www.gov.uk/government/publications/national-risk-register-of-civil-emergencies)

1 Defra. *Guidelines for environmental risk assessment and management. Green leaves III.*
2 *Revised Departmental guidance.* Cranfield University and Department for
3 Environment, Food and Rural Affairs, PB13670, London, UK, 79pp; 2011.

4 Economist Intelligence Unit. *The long view. Getting new perspective on strategic risk,* The
5 Economist Intelligence Unit Ltd., London, UK, 35pp; 2011.

6 Environment Agency. *Strategic risk assessment: phase II,* Environment Agency R&D project
7 E2-041/TR, Prepared for the Environment Agency by Galson Sciences Limited,
8 Environment Agency, Bristol, UK, 150pp; 2002.

9 Environment Agency. *Informing strategic decisions with comparative risk assessment: a*
10 *literature review.* Science report RIS-05-01. Prepared for the Environment Agency by
11 Cranfield University, Environment Agency, Bristol, UK, 46pp; 2005.

12 Ernst and Young. *The Ernst & Young business risk report 2010. The top 10 risks for*
13 *business. A sector wide view of the risks facing business across the globe,* Ernst &
14 Young Global Limited, London, UK, 45pp; 2010.

15 Foot, J. *Citizen involvement in local governance: summary,* Joseph Rowntree Foundation,
16 York, UK, 20pp; 2009

17 German Advisory Council on Global Change. *World in transition - Strategies for managing*
18 *global environmental risks.* Annual Report, German Advisory Council on Global
19 Change (WGBU), Springer, Berlin, Germany; 1998.

20 Government Office for Science. *Blackett review of high impact low probability risks,*
21 Government Office for Science, Report URN 12/519, Department for Business,
22 Innovation and Skills, London, UK, 45pp; 2011.

23 House of Commons. Science and Technology Committee. *Scientific advice and evidence in*
24 *emergencies.* Third report of session 2010-2011, HC498, The Stationery Office,
25 London, UK, 88pp; 2011.

26 International Risk Governance Council. *Report. The emergence of risks: contributing*
27 *factors.* IRGC, Geneva, Switzerland, 59pp; 2010.

28 International Risk Governance Council. *Concept note. Improving the management of*
29 *emerging risks. Risks from new technologies, system interactions, and unforeseen or*
30 *changing circumstances.* IRGC, Geneva, Switzerland, 43pp; 2011.

31 Klinke, A.; Renn, O. A new approach to risk evaluation and management: Risk based,
32 precaution based, and discourse based strategies. *Risk Anal.* 2002; 22(6); 1071-1094.

33 Lloyds. *Realistic disaster scenarios. Scenario specification v1.0 – 7th January 2013,*
34 Lloyds, London, UK, 55pp; 2013.

1 Morgan, K.M.; DeKay, M.L.; Fischbeck, P.S.; Morgan, M.G.; Fischhoff, B.; Florig, H.K. A
2 deliberative method for ranking risks (II): Evaluation of validity and agreement among
3 risk managers. *Risk Anal.* 2001: 21; 923-937.

4 Perhac, R.M. Comparative risk assessment: where does the public fit in? *Sci. Technol. &*
5 *Human Values*, 1998: 23, 221-241.

6 Pollard, S.J.T., Kemp, R.V., Crawford, M., Duarte-Davidson, R., Irwin, J.G., Yearsley, R.
7 Characterizing environmental harm: Developments in an approach to strategic risk
8 assessment and risk management. *Risk Anal.* 2004: 24; 1551-1560.

9 Prpich, G., Evans, J., Irving, P., Dagonneau, J., Hutchinson, J., Rocks, S., Black, E. and
10 Pollard, S.J.T. Character of environmental harms – overcoming implementation
11 challenges with policy makers and regulators. *Environ. Sci. Technol.* 2011: 45; 9857-
12 9865.

13 Risk and Regulation Advisory Council; *Response with responsibility. Policy-making for*
14 *public risk in the 21st century*, Report URN 09/948, London, UK, 40pp; 2009

15 Science Advisory Council. *Paper SAC(12)04. Risk issues.* Agenda paper for SAC meeting
16 12th January, 2012, Defra SAC, London, UK, 8pp; 2012.

17 Sparrow, M.K. *The character of harms. Operational challenges in control.* Cambridge
18 University Press. Cambridge, UK, 264pp; 2008.

19 Spiegelhalter, D., Pearson, M., and Short, I. Visualizing uncertainty about the future. *Science*
20 2011: 333; 1393.

21 US Environmental Protection Agency. *Unfinished business: A comparative assessment of*
22 *environmental problems.* U.S. Environmental Protection Agency (USEPA), Office of
23 Policy Analysis, Office of Policy, Planning and Evaluation. Washington, DC, US;
24 1987.

25 Willis, H.H.; DeKay, M.L.; Morgan, M.G.; Florig, H.G.; Fischbeck, P.S. Ecological risk
26 ranking: Development and evaluation of a method for improving public participation in
27 environmental decision making. *Risk Anal.* 2004: 24; 363-378.

28 Willis, H.H.; MacDonald Gibson, J.; Shih, R.A.; Geschwind, S.; Olmstead, S.; Hu, J.;
29 Curtright, A.E.; Cecchine, G.; Moore, M. Prioritizing environmental health risks in the
30 UAE. *Risk Anal.* 2010: 30: 1842-1856

31 Willows, R.I. and Connell, R.K. (eds.) *Climate adaptation: risk, uncertainty and decision-*
32 *making*, UKCIP report, United Kingdom Climate Impacts Programme, Oxford, UK,
33 154pp; 2003.

1 World Economic Forum. *Global risks 2011 6th edition. An initiative of the risk response*
2 *network*. A World Economic Forum Report, Switzerland, 56pp; 2011; available at
3 <http://riskreport.weforum.org/>

Scientific commentary: Strategic analysis of environmental policy risks-heat maps, risk futures and the character of environmental harm

Prpich, George

2013-10-01T00:00:00Z

NOTICE: this is the author's version of a work that was accepted for publication in Science of The Total Environment . Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in Science of The Total Environment, Volumes 463–464, 1 October 2013, pages 442-445, ISSN 0048-9697, <http://dx.doi.org/10.1016/j.scitotenv>

G. Prpich, J. Dagonneau, S.A. Rocks, F. Lickorish, S.J.T. Pollard, Scientific commentary: Strategic analysis of environmental policy risks—heat maps, risk futures and the character of environmental harm, Science of The Total Environment, Volumes 463–464, 1 October 2013, pages 442-445, ISSN 0048-9697, <http://dx.doi.org/10.1016/j.scitotenv.2013.06.037>.

<http://dx.doi.org/10.1016/j.scitotenv.2013.06.037>

Downloaded from CERES Research Repository, Cranfield University