Environmental science, economics, and policy: A context-sensitive approach to understanding the use of evidence in policy-making

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Thesis Abstract

The scale of human impacts on the environment means that ecological and environmental sciences are strongly motivated by the need to take urgent measures to halt environmental damage, to conserve at-risk species and ecosystems, and to preserve rapidly depleting stocks of natural resources. Resource and time constraints mean that actions must be taken with clarity, direction and, crucially, *impact*. Evidence that informs policy decisions operates alongside a range of other societal considerations, which may be economic, moral, social, and political. Science is one of many inputs to the decision-making process. Policy change occurs within social parameters that are influenced by a range of non-evidentiary, contextual, and policy factors. This thesis explores the *intermittent* variables and strategic factors that bring conservation science to the forefront of environmental policy at any one time. These include the construction of strategic narratives that communicate scientific information in the policy arena, the interaction between expert credibility and policy relevance, and the role of pre-existing values and beliefs on the passage of evidence from scientific production to societal decisions. I applied mixed-methods approaches to the analysis of Internet surveys, face-to-face interviews with key policy actors, and cluster analysis of belief scale responses across UK and USA case studies. I applied a number of policy and science-technology frameworks and applied methodological approaches to understanding the role of evidence in the policy process. Overall, the findings of this thesis suggest that non-evidentiary factors in the policy arena interact with scientific evidence through a range of contextual variables. These include professional values, interest group interactions, the power and salience of influential individuals, and the trans-scientific strength of strategic policy narratives and evidence from different disciplines. This has important implications for how policy-makers use evidence, and should shape the research community's understanding and approach to research coproduction, communication, and evaluation.

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Authors Declaration

I confirm that this thesis is my own work and that it has not been previously submitted to the University or any other institutions. Elements of chapter I, specifically the sample frame and survey design were assessed as part of my MSc dissertation. However, the analysis of results, research questions, and literature and discussion sections were all completely overhauled during the course of my PhD, through multiple revisions with the Ecosystem Services journal. I therefore submit this as an original contribution that sets the scene for subsequent chapters.

Introduction: Deshrouding science-policy impact

In recent years the UK Government has placed increasing emphasis on the need to provide evidence of the economic and social returns from investments in research (Research Council Economic Impact Group, 2006). A growing number of commentators, including the funder of this research, the Economics and Social Research Council (ESRC), have called for research impact considerations to operate through a broader and more holistic framework that includes the non-direct influence of the evidence (ESRC, 2009, 2011). The challenge is to look deeper than standard academic impact, and quantify the effects that academic research has on broader society (Molas-Gallart et al., 2000; Pettigrew, 2011).

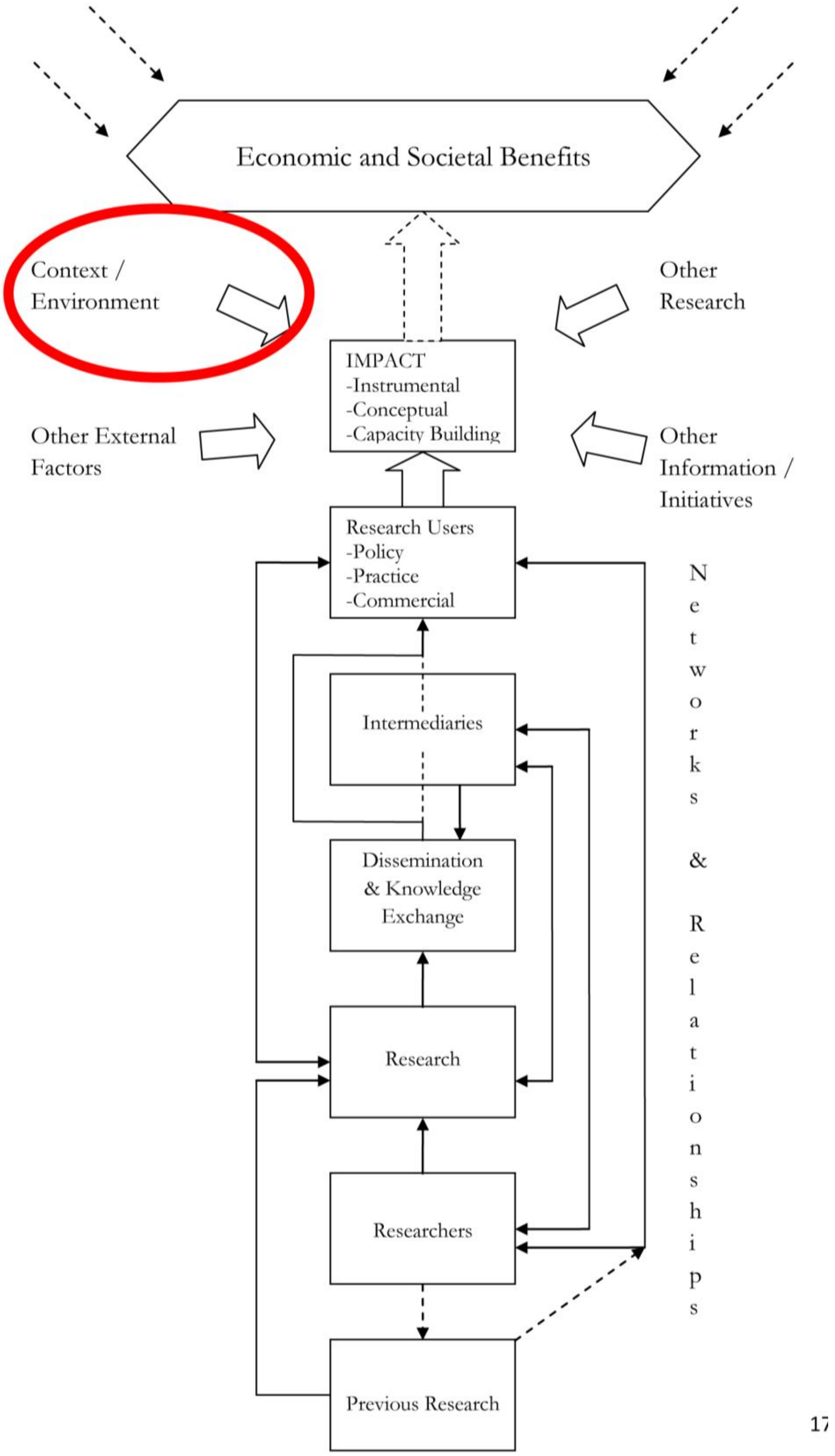
The implication is that future impact evaluations should factor in the medium- and long-term impacts of research outputs by extending the scope of assessment beyond direct academic or economic impact, to include its use in political and societal venues (ESRC, 2009, 2011). This approach is formalized in the new system for assessing the quality of research in UK higher education institutions: the Research Excellence Framework (REF). The REF encourages academic research producers to redefine impact in a broader way that encompasses impact upon the economy, society, public policy, culture and the quality of life (REF, 2011). These new approaches to research evaluation have considerable advantages over traditional measurements of academic citations (Tijssen et al., 2002; Zitt et al., 2005). By accounting for a broader range of possible impacts, they capture a more diverse and potentially diffuse range of impacts across a wider selection of societal stakeholders (Owens, 2013).

Despite these recent concessions to the broader sites of research impact, there is still a lack of joined-up understanding of the ways in which research interacts with substantive social and policy realities (Contandriopoulos et al., 2010; Pettigrew, 2011). The extent and nature of how research influences policy and practice "depends on the ways in which these messages are delivered and the environment into which they are delivered" (ESRC, 2009, p. 4). Importantly:

"The context in which research messages are communicated has a bearing on their possible impact. A study may have met all the pre-conditions for generating impact, but if its findings happen to emerge at a time when policy makers and practitioners are not open to such ideas, the scope for influence is greatly reduced" (ESRC, 2009, p. 15).

This research thesis is addressed towards the problem of how context affects the uptake and utilization of evidence. The role of non-evidentiary contextual factors has largely gone underappreciated in the literature (exceptions include Dunlop, 2014; Pettigrew, 2011). The impact of research operates in many ways, whether instrumental (for example, influencing the development of policy, practice or service provision, shaping legislation, altering behavior), conceptual (for example, contributing to the understanding of these and related issues, reframing debates), or diffuse ‘knowledge creep’ (Nutley et al., 2007; Weiss, 1980). There is recognition that non-instrumental impacts are difficult to quantify, likely to be contributory, non-linear, and dependent on the particular contexts in which evidence was utilized (ESRC, 2009). They are nevertheless a vital element in impact evaluation, and represent a significant gap in our understanding of how and why impact is generated. This gap is identified by the arrow labelled ‘context/environment’ in the ESRC Impact Framework Model (see circled section, Figure 1).

Figure 1 - ESRC Draft Impact Framework Model (2009, p. 17, circle added by author)



A broader approach to understanding research impact requires the inclusion of a broader set of social impacts (Pettigrew, 2011). My chosen area of social impact was the decision-making process, focusing in detail on knowledge emanating from the scientific research community, and the processes by which it impacts on policy development, directly and indirectly, through the prism of contextual societal and political features (Earl et al., 2001; Frederiksen et al., 2003; Pettigrew, 2011). Academic literature, and in particular Science and Technology Studies (STS), shows that there is no single, pre-set route along which knowledge unfolds (Jasanoff, 2004; Jasanoff and Wynne, 1998; Yearley, 1988). This presents challenges to the disaggregation of research impact. Science will necessarily "be just one of many inputs" in societal decision-making (Wittrock, 1991, p. 347). Research impact assessment must, therefore, account for the political and societal 'non-evidentiary factors' that affect the wider utilization of evidence. Evidence nevertheless plays a key role because of the authoritative place science holds in societal decision-making discourse (Cozzens and Woodhouse, 2002; Jasanoff, 2005; Jasanoff and Wynne, 1998). Habermas (1985) identified three rational claims that may legitimately influence decision-making. The first are assertions to truthfulness based on empirical method or proven results. These operate alongside established norms (informal understandings that govern society's behaviors), and value judgments (group conceptions of the relative desirability of things; Scott and Marshall, 2009). Enlightenment claims made for the 'scientific' basis of measures or decisions derive their validity from an ideal-type of science as yielding objective information "not biased by personal interests) and cognitively valid information (logically consistent, of high empirical quality and explanatory value" (Knorr, 1976, p. 172). Facts have a special place in this system because assertions of truth "signify that the asserted state of affairs exists as something in the objective world", and are open to objective judgments (i.e. can be challenged and held accountable) (Habermas, 1985, p. 50).

Understanding the influence of scientific evidence in this way opens up the question of the "role of external factors in the construction of scientific knowledge" (Yearley, 1988, p. 39). It has been shown that knowledge is used in policymaking in different ways, not only in direct and instrumental forms, but also strategically (Amara et al., 2004; Dunlop, 2014; Knorr, 1976), with science "introducing new ideas, or providing ammunition in political arguments" (Wesselink et al., 2013, p. 1). Science-policy impact may be achieved through multiple pathways, including popular media reporting, societal framing events (natural disasters, economic crashes), advocacy campaigns, and the power and influence of individuals and organizations (Nelkin, 1995; Wynne, 2002).

Scientific information about the state of the world 'out there' interacts with social and policy processes at the *science-policy interface* (SPI). SPIs are defined as "social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making" (van den Hove, 2007, p. 1). These are the processes by which members of society "test and deploy knowledge claims used as a basis for making collective choices" (Jasanoff, 2004, p. 9). I focus in this thesis on the interface between conservation science, economic evidence, and environmental policy.

Conservation science at the interface of policy

One of the benefits of taking an interdisciplinary approach to the question of research impact is the opportunity to attend conferences in a range of disciplines. Differences in how the science-policy interface was understood between attendees of conservation and political science conferences were illustrative to my early research focus. At the 2013 International Conference on Public Policy in Grenoble, for example, there was broad appreciation that science is one of many inputs into the decision-making process, and comfort at the political and strategic uses to which it is put in the policy process. In contrast, at the 2013 International Association for Ecology Conference, the floors rang with calls for policy-makers to heed the scientific advice of the ecological community. 'Policy', 'policy-making', and 'policy-makers' were commonly portrayed as an unknowable black-box, mysterious and many-times removed from the world of research. There was uncertainty at what was involved in the decision-making process, and suspicion that lack of action on environmental issues stemmed from a failure of the science-policy process (see Larigauderie et al., 2012 for an example of this discourse).

Although anecdotal, these different perspectives are echoed in the conservation science literature. The science-policy gap is commonly invoked to refer to the interchange of knowledge between different institutional 'worlds' or 'communities' (Beyer, 1997; Caplan, 1979). Typically this is portrayed as between the 'creators' (e.g. science) and the 'users' (e.g. policy) of knowledge (Greaves and Grant, 2010; Guston, 2001; King, 2005; Lawton, 2007; Watson, 2005). The 'deficit' model assumes that increasing or improving the quality and transfer of scientific evidence (the supply of knowledge) can lead to improvements in the decisions society makes on the ground (Brown, 2009; Huntington, 2007; Sturgis and Allum, 2004). Scientists have a duty to increase the likelihood of their research reaching policy audiences, for example, by better presentation and delivery of the products of their research (Holmes and Clark, 2008; Nutley et al., 2007; Watson, 2005). The search for impact is motivated by a sense of accumulating evidence of real-world problems like biological diversity loss (Barnosky et al., 2011), natural resource depletion (Browning, 2013; Deffeyes, 2008), and catastrophic climate change (Weitzman, 2011). In the face of these challenges, conservation scientists may no longer satisfy themselves with "curiosity, logic and validation", but must address the "most urgent needs of society" to inform policy and management decisions of the utmost importance (Lubchenco, 1998, pp. 494–5).

At the theoretical level, the deficit model follows a conception of evidence use that envisions two worlds: scientific knowledge producers, and policy knowledge users (McNie, 2007; Sarewitz and Pielke Jr., 2007). Improving 'impact' in this linear model is typically a matter of better communication, timeliness, and accessibility (see, e.g., Clark, 2007; Nutley et al., 2007), more integrity for science (higher legitimacy, more independence, methodological rigour, see e.g., Lubchenco, 1998), or of rationalising policy through guidelines and rules on scientific input in the policy process (e.g., the evidence-based policy movement, see Young et al., 2002). If we can only shout clearer and louder, decision-makers will come to their senses.

However, fundamental challenges to the linear model have been raised (Jasanoff, 2004; Owens et al., 2004; van den Hove, 2007), and there is increasing appreciation that knowledge is used in policymaking in different ways, both conceptually and symbolically (Amara et al., 2004; Cowell and Lennon, 2014; Jasanoff and Wynne, 1998). It has been argued that the impact of scientific research is better thought of as 'diffuse', contributing to the 'enlightenment effect' of societal understanding through a gradual accumulation of ideas and concepts over time (Amara et al., 2004; Weiss, 1980, 1977). However, to date this has been difficult to capture empirically, since evidence which does not have immediate instrumental impact upon academic publication or profit-making enterprise builds up diffusely, until the aggregated strain it exerts forces a shift in dominant science-based narratives (following the paradigm shift model of Kuhn, 1962). This provides a 'reservoir' of information into which the user community can dip (Beyer, 1997). These ideas are, in true enlightenment fashion, gaining gradual acceptance in policy and practice, where consideration of the quality and impact of a body of evidence is now being applied to policy appraisal in the UK (DFID, 2013). Nevertheless, the methodological tools for assessing diffuse impact have been underexplored to date.

A great deal of research effort has focused on understanding the interpersonal interaction of researchers with the policy sphere (and vice versa, see e.g., van den Hove, 2007; van Kammen et al., 2006; Vogel et al., 2007; Young et al., 2014). A wide body of literature exists that maps the array of social processes, actors and organizations that operate across different policy contexts (for overview, see Young and Watt, 2013). Science Policy Interface (SPI) literature is keenly focused on the practical side of improving the exchange of information and their ultimate influence on decisions (van den Hove, 2007; Young et al., 2014), encouraging researchers to better understand the science and policy landscape within a particular context, with a view to targeting their methods of impact (Timaeus et al., 2012). This requires identification policy and science contacts, clear understanding of the policy area researchers are trying to interface with, and managing trade-offs between the benefits and risks of enhanced connections with policy contexts (Cash et al., 2002; Sarkki et al., 2013).

Much work has also been done on understanding how science and policy interact with each other at the institutional level, across the science policy interface (Cent et al., 2011; Crewe et al., 2002; Vicente and Partidário, 2006). This research has forged ahead in reframing the question of science-policy impact away from linear models of instrumental use, towards more context-sensitive understandings of the real-world processes and barriers that exist at the science-policy interface (Oldham and McLean, 1997; Sheate and Partidário, 2010; van Kerkhoff and Lebel, 2006).

It is with a view to this continued effort to understand and map policy context, and the ways in which they impact on evidence utilization, that the papers presented in this thesis aim. At the simplest level, my major research question is: What role does science play in the policy-making process?

To explore the major research question, further questions were raised. First, what other factors, apart from evidence attributes, affect the influence of evidence in the policy process, and how can we characterize and measure these context-sensitive *intermittent variables*, defined here as factors present in the social or political receptivity of scientific research that may occur at irregular intervals and in varying quantity. Second, what tools are available for analyzing the influence of policy context on the utilization of scientific evidence? Finally, how comparable are the findings of contextual impact across various case studies encompassing different policy subsystems and national jurisdictions?

In the next section I outline the theoretical approach applied to these research questions in this thesis. In the conclusion I revisit these research aims, outline common findings, and suggest lessons on how to understand and improve the way science informs policy that will be of relevance for the assessment of research projects going forward.

Theoretical approach

Taking the starting point that science is ‘one of many inputs’ to the policy-making process, a contextual approach to research impact assessment asks: what factors affect the utilization of scientific knowledge and what are the other considerations that decision-makers take into account in the policy process?

The focus here is specifically on the *non-evidentiary* factors that are taken into account in policy decisions, and that form the context in which scientific knowledge is or is not able to influence policy outcomes (Pettigrew, 2011). Context is a broad term that may apply to political factors, policy processes, institutional structures, public perception, public values, belief systems, norms and regulations that exist in in terms of ‘coproduction’ of social constructed knowledge (Jasanoff, 2004; Jasanoff and Wynne, 1998). There is increasing appreciation that the interactions between research and policy are complex and multi-directional, involving a range of social and cultural factors (Cozzens and Woodhouse, 2002; Yearley, 1988; Young et al., 2014). Scientific knowledge does not simply accumulate to the point where it influences policy (Jasanoff, 2005), but is dependent on the wider social milieu (Kuhn, 1962). Science and Technology Studies (STS) analyse these processes of coproduction (Jasanoff, 2005, 2004; Jasanoff and Wynne, 1998), envisioned as explicitly social processes of negotiation and deliberation that arise through the interaction of scientific knowledge with contextual factors like normative beliefs and policy-maker judgment (Hoppe, 2009; Kaplan, 1993; Stone, 2002). The challenge, taken up in this thesis, is to make these processes visible: to deshroud the black box of evidence use in the policy process. Throughout this thesis I apply the theoretical insights of these schools of thought to better understand and analyze the role of evidence in its interactions with contextual factors.

Impact may be heavily dependent upon the “receptive contexts” around a body of research (Pettigrew, 2011, p. 351). Impact in this sense is a “complex process which cannot be isolated from context” (Earl et al., 2001, p. 7). Context is theorized to operate on two levels: the various actors with which evidence interacts (e.g., government departments, communities, non-government organizations (NGOs)), and the pressures through which its message is shaped (including social, political cultural, economic, historical and environmental factors; Earl et al., 2001). In response, some authors have called for a toolkit “to decode context and understand its impact on knowledge use” (Contandriopoulos et al., 2010, p. 468).

One approach to the problem of capturing contextual influences would be to map a particular policy context, defined as the substantive policy subsystem into which evidence is expected to impact. By analyzing the characteristics of each policy subsystem, it may be possible to qualify and assess the influence that contextual factors have on research utilization. In this way the case study approach could be used to compare the ways in which different contextual factors affect the uptake of evidence. The tools exist, in public policy analysis, that allow us to model the policy process, identify causal drivers of policy-related outcomes, and compare between policy subsystems (for example, the public policy frameworks of Baumgartner, 2006; Jones and McBeth, 2010; Sabatier and Jenkins-Smith, 1993). The problem with this approach is that any mapping or modeling of the policy process will provide only a small glimpse of the full contextual picture. A common criticism of such positivist approaches is that they are bound to generalized linear models which can give a false impression that the researcher has identified a key independent variable that accounts for differences in the dependent variable of evidence utilization in different case studies. However, one can never be sure that their model did not miss out some confounding factors or interactions that went unobserved in their analysis (Berg-Schlosser et al., 2009; Rihoux and Lobe, 2009).

Another way of approaching the question of context is to analyze the ways that evidence interacts and is influenced by a proscribed range of non-evidentiary factors. The focus here is on the interactions of evidence with a narrower set of identifiable policy factors. For example, we may analyze research utilization from the perspective of its perceived credibility or salience to policy audiences (Cash et al., 2002; Tuinstra et al., 2006). The interest here is not around increasing the salience of a piece of research to make it more relevant and impactful. Rather, the focus is on how scientific evidence is perceived by those groups that make up the policy subsystem (note, the policy subsystem in this defintion is made up of a range of actors, including policy-makers, researchers, NGOs and practitioners; Sabatier and Jenkins-Smith, 1993).

The task is to identify the presence of non-evidentiary influences that operate on the utilization of evidence. Three contextual factors are explored in this thesis. First, personal attitudes and beliefs are theorized to operate as a filter on new information (Henry, 2011; Lord et al., 1979; Munro and Ditto, 1997), allowing the researcher to track the attitudes and beliefs that operate on actors at the science-policy interface using statistical techniques for interpreting shared beliefs and attitudes on value scales (Schwartz, 1992; Stern et al., 1998)[1]. Second, the construction and dissemination of narratives has been posited as the primary mechanism by which individuals organize, process, and convey information (Herman, 2004; Jones and McBeth, 2010; Stone, 2002). Interpretations of meaning assigned to narratives of facts and values (Fischer, 2003; Fischer and Forester, 1993; Roe, 1994; Stone, 2001), can be analysed as a way of tracking the strategic use of information by which expert-based evidence is made compatible with the policy process (Hajer, 1993). Third, the ability of well-connected individuals and well-resourced groups to advocate and influence is widely-recognized, but rarely explicitly accounted for in research impact evaluations (Lindblom, 1959; Sabatier and Jenkins-Smith, 1993). By focusing on the role of advocacy, interest group formation, and personal influence, I aim to capture the complex range of influences that shape the utilization of evidence at the science-policy interface. This is not

[1] A belief is an internal feeling that something is true, even though that belief may be unproven or irrational. Values are stable long-lasting beliefs about what is important to a person. They become standards by which people order their lives and make their choices. An attitude is the way a person expresses or applies their beliefs and values. Attitudes are the mental dispositions people have towards others and the current circumstances before making decisions that result in behavior. People primarily form their attitudes from underlying values and beliefs. Attitudes are expressed through words and behaviour.

an exhaustive list. However, it demonstrates the range of potential factors that operate on the utilization of evidence in various social and policy contexts.

The common thread running throughout this thesis is the question of how to understand and improve the way science informs policy. I adopt methods and approaches from research impact assessment, team science case study approaches, public policy analysis, discourse analysis, and science and technology studies. I apply mixed-methods approaches throughout, combining quantitative analysis with qualitative coding of interview and open-end survey data. This provides insights from a range of methodological and epistemological perspectives (positivist and interpretative). This allows for analysis of the strengths and weaknesses of each approach in the conclusion to this thesis. By comparing several approaches to examine the same phenomenon, it is possible to build a set of best practice recommendations for the contextual assessment of research impact (Jick, 1979; Johnson and Onwuegbuzie, 2004).

In the final conclusion to this thesis I present a comparison of the common findings, methodological insights and policy implications of the case studies presented here. I bring together my findings, to test the strengths and weaknesses of each method from perspective of contextual impact. The ultimate aim is that, over time, it may be possible to qualify contextual variables that have been identified across multiple case studies, with a view to building a set of broader regularities of contextual factors among science policy interfaces. Intermittent variables are by their nature varied and various. The response is necessarily interdisciplinary. The remainder of this thesis explores which tools can be used to highlight the interactions between evidence attributes and contextual factors.

The thesis is written in a paper-based style. It consists of five papers divided by theme into three parts. Part One presents a study on the production of scientific research, with a view to identifying the contextual factors that affect the creation of environmental knowledge. Part Two tracks the role of evidence with relation to the influence of contextual factors within the case study of the Natural Environment White Paper. Part Three analyzes the influence of values and attitudes on evidence utilization and research production. Methodological innovations are attempted throughout. All papers are written in the style of the academic journals to which they have been submitted for publication. Three chapters (Chapters I, II, and IV) have already been accepted for publication in academic journals. Chapter III is undergoing revisions following review in Research Policy. Chapter V is in the final stages of preparation for submission to PLOSOne. Reference style reflects the format in which each paper was accepted/submitted for publication in the relevant journal.

Part One – Contextual factors and research production

Conservation science research, even in the production phase, is multi-faceted, complex, and dependent on a range of contextual social and procedural factors (Dunlop, 2014; Jasanoff and Wynne, 1998; Yearley, 1988). Science is not created independent of personal values, belief and attitudes (Fisher, 1990; Latour, 1987), nor is it free from political pressure or personal influence (Bijker et al., 2009; Collins, 1992; Cozzens and Woodhouse, 2002). Conservation science, in particular, is idealized as a crossdisciplinary amalgam of social science, natural science, ecology and economics (Lawton, 2007; Pigliucci, 2002; Pullin et al., 2009). This makes it an important site for understanding the interactions of multiple scientists, epistemological foundations, and methodological approaches (Watson, 2005; Waylen and Young, 2014). This paper provides empirical research on the production side of the research impact question. The identification barriers and unforeseen interactions in the production of research therefore provides an indication of the non-evidentiary and contextual factors that exist from the earliest stages at the science-policy interface (Mâsse et al., 2008; Stokols et al., 2008).

Chapter I. Crossdisciplinary research contributions to the United Kingdom's National Ecosystem Assessment. Lawton and Rudd, Ecosystem Services 2013, 5, 149-159

An initial study on the role of evidence was undertaken as part of my MSc dissertation. As part of my 1+3 ESRC-funded PhD, the MSc laid preparatory ground for my PhD. Much of the initial literature review and identification of research gaps was undertaken here. The sample frame and survey design used in the attached paper were developed as part of my MSc dissertation. However, the analysis of results, research questions, literature, and discussion sections were all completely overhauled during the course of my PhD, through multiple revisions with the Ecosystem Services journal.

I include the finished paper as the first substantive chapter of the PhD thesis. This study set the scene for the UK case study that comprises the first half of the thesis. It provides an in depth study of the knowledge production process from the perspective of crossdisciplinary collaboration. The UK National Ecosystem Assessment (UKNEA, 2011) was a large-scale independent synthesis of existing academic evidence within an ecosystem service frame. It brought together over one thousand three hundred scientists from multiple disciplines from across the UK, and was divided between countries (England, Scotland, Wales, Northern Ireland), habitats, and ecosystem services. Set within a large-scale team science project encompassing the research of natural scientists, economists, and social scientists from academic, private, government, and non-governmental organizations, this paper contributes to the literature on crossdisciplinary theory and measurement, assessment of team science projects, and ecosystem service valuation. This paper contributes to understanding of the production of ecosystem service research, a fruitful area for research into the knowledge creation process in recent years (Reid, 2006; Rothman et al., 2009; Waylen and Young, 2014). Ecosystem assessments cover processes and data creation from a range of disciplines and fields of expertise. As such they represent a valuable site for understanding the complex knowledge coproduction processes and diverse and interacting forms of knowledge use (Waylen and Young, 2014).

I applied case study approaches for understanding 'team science' initiatives. Starting from the position that science initiatives are "strongly influenced by social and interpersonal processes", such as collaborative styles and behaviors, interpersonal conflicts, and negotiation strategies (Stokols et al., 2008, s81), I tracked the antecedents, processes, and outcomes of scientific production through survey, interview, observational, and archival measures (Stokols et al., 2003, 2008). It provided empirical data on the development and production of one of the key evidentiary papers informing the Natural Environment White Paper, *The Natural Choice* (Defra, 2011). This gave a viewpoint into the 'how' of science production, and was an appropriate starting point for subsequent research on the influence of ecosystems science in the policy process, and the contextual implications, in terms of the barriers – institutional, contextual, and personal – that were found to affect research production.

As noted elsewhere, exploring the processes of developing the UKNEA provides us with an understanding of the role of such assessments in knowledge communication and coproduction (Waylen and Young, 2014). This paper also addresses the potential policy impact implications that stem from different levels of crossdisciplinary integration. It develops a conceptual framework for assessing the economically efficient level of investment in crossdisciplinary research that is revisited in later papers on the tradeoff between evidence attributes and impact (Chapter III) and the nature of professional attitudes towards the science-policy interface (Chapter V).

Part Two. Evidence influence on the development of the Natural Environment White Paper in the UK

The UK is at the forefront of experimental techniques to develop natural capital and ecosystem service methodologies within decision-making. The substantive area of policy analysis for Part Two was the Natural Environment White Paper, (Defra, 2011). White Papers are documents produced by the UK Government setting out details of future policy on a particular subject. A White Paper will often be the basis for a Bill to be put before

Parliament, but the Natural Environment White Paper was designed to set clear high-level policy direction for the environment in local and national decision-making. It represents the most important shift in conservation policy in the United Kingdom for over twenty years. It formalized the ecosystem services approach within policy objectives and emphasized the economic benefits of ecosystem services, national natural capital accounting, and the effects of ecosystem services on human health and well-being.

The focus on the specifically policy-based outcomes of conservation science in this case study led me to test a number of policy analysis frameworks. My initial aim was to apply policy analysis tools to map out the political context in which scientific research was put to use, with a view to capturing a more complete and comprehensive picture of the interactions between science and policy. To this end I applied policy models chiefly as a tool to aid understanding – toolboxes for conceiving and analysing the complexities of on-the-ground policymaking[2]. A wealth of policy process models exist that can be used "to conceptualize the use of information in a large, messy policy process, far removed form the idea that 'the evidence' has a direct input to a clearly definable process" (Cairney, 2014, p. 10). The White Paper provided the setting for two academic papers that applied different policy analysis frameworks to the question of conservation science impacts. In each paper I applied different analytical frameworks, using novel mixed-methods approaches, which led to findings and conclusions that are of direct relevance to contemporary environmental policy in the UK and elsewhere.

Chapter II - Strange Bedfellows: Ecosystem Services, Conservation Science, and Central Government in the United Kingdom. Lawton and Rudd, Resources 2013

Chapter II came about as a result of preliminary analysis of the Natural Environment White Paper and its supporting documents. The White Paper was preceded by extensive public consultation inviting written responses from interested parties. I conducted a content analysis and coded thirty-six consultation responses with NVivo 10 (http://www.qsrinternational.com) obtained from exhaustive online searches.

I used these consultation responses as material to test the usefulness of the Advocacy Coalition Framework (ACF) to the analysis of UK environmental policy over this period. Five groups who submitted comments were considered: central government; conservation scientists; landowner groups; environmental agencies, including the Department for the Environment, Food, and Rural Affairs (Defra) and its arms-length

[2] Ostrom distinguishes between *frameworks*, which identify relevant concepts and help organize analysis and theoretical comparison; *theories*, which make general assumptions about the causal relationships between concepts; and *models*, which make particular assumptions about particular objects of enquiry (Ostrom, 1999, pp. 39–40).

implementation bodies, the Environment Agency, and Natural England; and ENGOs. This method provided a valuable source of primary data for policy analysis. I applied novel methods to quantify documentary analysis, exploring the explanatory power of quantitative coding observations. Codes were divided into deep, policy and secondary belief levels for each coalition based on ideological closeness with pre-coding deep core issues, centrality to the substantive policy issue, and implementation practicalities (Sabatier and Jenkins-Smith, 1993).

This technique allowed me to explore coalition agreement and issue alignment based on observations shared by the groups submitting White Paper consultation. This showed that convergence existed among various conservation policy actors at the policy core and secondary belief levels, including broad agreement that the ecosystem service approach was a positive progression in environmental management.

Using these findings expanded a perspective on the short- to long-term sustainability of policy partnerships between advocacy coalitions, based on the hierarchy of deep, policy and secondary beliefs. This chapter applied some of the more novel elements of recent ACF work to the interaction of long-term values and short-term interest with reference to the policy applications of environmental science (Mahoney, 2007). The form of ecosystem policy adopted was anticipated to depend strongly on the context in which it was developed. This highlighted two sets of pressures operating simultaneously. The first were modelled around concepts and ideas in the scientific-political coproduction arena, including academic pressures, market pressures, and political pressures like decentralization and budgetary constraints. The second were national pressures. We noted that different political jurisdictions offered different receptive contexts to ecosystem ideas. Finally, we explored concerns, prevalent in the conservation community, of the risk of ecosystem policy that co-opts only ecosystem service and ecosystem valuation messages at the expense of the ecological systems understanding of the broader ecosystem approach.

Chapter III - Negotiating ecosystem concepts in the 2011 UK Natural Environment White Paper. Lawton and Rudd, Research Policy, 2014.

Chapter III represented the first major empirical contribution of the PhD thesis to the academic literature. I assembled a sample of around fifty actors involved in the development of research or policy that contributed to the outcome of the Natural Environment White Paper. This sample represented a broad church of professional backgrounds and organizational affiliations, including members of: Defra and its arm’s-length bodies (the Environment Agency, Natural England, English Nature and the Forestry Commission) involved in project management or scientific monitoring; ex-Ministers with environment portfolios; policy heads of national-scale environmental NGOs; landowning organizations like the Country Land and Business Association (CLA) and National Farmers Union (NFU); the Government's White Paper Ministerial Advisory Panel; and academia.

I tested the applicability of a range of methodological and theoretical foundations. Initially I intended to work within the Advocacy Coalition Framework (ACF). The attraction of this framework is that it conceives of knowledge being generated, negotiated and understood in the context of individual's values, beliefs and interests (Sabatier and Jenkins-Smith, 1993, 1999). It encourages the researcher to account for the role of beliefs, which act as perceptual filters that 'screen out dissonant information and reaffirm conforming information' (Sabatier and Weible, 1999, p. 194). Visualizing the policy process through an ACF lens helps to explain why scientific evidence does not always enjoy instrumental impact (it interacts with personal beliefs and coalition interests in the policy process). However, a number of concerns arose as I attempted to apply it to uncovering the contextual variables that might help to qualify the role that scientific knowledge had on the development of an ecosystem approach in UK environmental policy.

First, the ACF steers research towards a particular dependent variable, asking what processes lead to policy change. In the case of the White Paper, the occurrence of policy change is already given (the shift to a new policy paradigm has occurred, in the UK). Methodologically, the idea of actor coalitions, which was so useful in Chapter II, was less helpful here. The ACF predicts that actors will normally organize in two opposing coalitions, based on two opposing belief systems (Sabatier, 1999; Sabatier and Jenkins-Smith, 1993). There was no clear cleavage in attitudes in survey interviews. Consequently, the risk was that the data would be forced to fit the assumptions and expectations set by ACF theory, causing less, not more, explanatory power for the role of non-evidentiary factors in the development of the White Paper. The limitations of the Advocacy Coalition Framework for analyzing the influence of policy context on the utilization of scientific evidence are explored in depth in the concluding chapter of the thesis.

I turned to tools provided by interpretative policy analysis via the Narrative Policy Framework (NPF), an approach based on the same theoretical foundations as the ACF, but that focuses on the construction and dissemination of policy narratives as the primary mechanism by which individuals organize, process, and convey information (Jones and McBeth, 2010; Shanahan et al., 2011). The NPF stems from a range of disciplines, from literary studies to computer science and social psychology (Gerrig and Egidi, 2003; Golding et al., 1992; Herman, 2004; McComas and Shanahan, 1999; Schank, 2000). Primary among these is an interpretative approach to policy analysis which focuses on the meanings of policies, on the "values, feelings, and/or beliefs which they express, and the processes by which those meanings are communicated to and 'read' by various audiences" (Yanow, 1996, pp. 8–9).

I applied Interpretative Policy Analysis (IPA) and NPF qualitative coding approaches to interview responses. First I questioned the data for evidence-based narrative strategies they revealed at the micro-level, using discursive techniques outlined by the NPF (following Radaelli et al., 2013). Second, I applied IPA to how policy actors constructed different stories, and how they used facts and metaphors in policy narratives (Dryzek, 2005; Stone, 2002). The IPA provides a set of discursive strategies that are commonly used in science-policy communication. For instance, policy metaphors draw comparison between one narrative and another. They assume certain similarities between situations, and imply prescription and judgments about the correct interpretation of knowledge. They aim to 'scale-up' issues by associating them to problems of greater perceived societal weight. Finally, causal stories link a problem's cause to a wider effect that bestows greater authority on groups offering certain solutions (Stone, 2002).

The substantive issues raised by the White Paper provided a case study of the strategic use of evidence studied through discursive analysis (for precedents see Dunlop, 2014; Radaelli et al., 2013). The White Paper represents the mainstreaming ecosystems approaches to conservation science and management in UK policy (following international advances such as the Convention on Biodiversity COP10, 2010; Costanza et al., 1997; Defra, 2007; Millennium Ecosystem Assessment 2005). The ecosystem frames current expert understanding of ecological science (Kwa, 2002; Raffaelli and White, 2013), and the ecosystem approach has been successfully used in policy by conservation organizations under terms like the 'landscape approach' and 'Futurescapes' (RSPB 2010). At the same time, economic narratives of 'ecosystem services' have become increasingly prominent in environmental regulation over the past decade (Cowell and Lennon, 2014; Gómez-Baggethun et al., 2010; Sarkki et al., 2013). The shift from traditional forms of conservation, focusing on protecting individual species and habitats (Franklin, 1993) to preserving and improving the integrity of ecosystem functions (Christensen et al., 1996; Slocombe, 1993) is an important episode of policy change in the UK, with potential implications at the international level (e.g., international commitments to halt biodiversity loss following COP10, 2010).

I applied the theoretical insights of Science Technology Studies (STS) literature to explore the rise of ecosystem concepts in the development of the Natural Environment White Paper. An important concept throughout this paper is 'co-production', referring to the processes that connect the production of knowledge with the organization of policy-making (Jasanoff, 2004; Jasanoff and Wynne, 1998; Tuinstra et al., 2006). Understanding the negotiation of knowledge in society requires an understanding of the social processes of deliberation that lead to acceptance of new scientific concepts, like ecosystem science, in policy decisions (Fischer and Forester, 1993; Stone, 2002).

The framework adopted in this paper qualifies the role of context through the interaction of evidence with trade-offs of attributes of credibility (associations with the scientific method, claims to objectivity etc.), legitimacy (perceptions of fairness, appropriateness, and acceptance by multiple audiences), and salience (relevance to the public or decision-makers, following Cash et al., 2002). Following an increasingly fruitful line of inquiry, the relative credibility, legitimacy, and policy relevance (salience) that ecosystem metaphors command in the policy arena is important in the development of ecosystem knowledge and policy governance (Cash et al., 2002; Sarkki et al., 2013; Tuinstra et al., 2006). I explored the applicability of this framework to contextual impact. I modeled three regions where different balances of trade-offs and distance of expertise to policy salience affect the utilization of evidence. The balance of these attributes was shown to operate differently depending on their interaction with different policy actors and strategic narratives. This could have important implications for how policy-makers use evidence and should shape the research community's impact objectives, by showing how contextual factors dictate what is considered legitimate and relevant, and in turn has impact on decisions.

Part Three – The influence of values and attitudes on evidence utilization

The way in which we frame research utilization will influence the kind of impact we observe. Our perceptions of research influence are dictated to some extent by our world view (itself influenced by our underlying values and beliefs - see Schwartz, 1992; Stern et al., 1998), and our understanding of the science-policy interface: the institutions and process that govern the interaction of research with user communities.

I found a useful conceptual framework tucked away in a chapter of an edited book from the early 1990s. The work of Wittrock (1991) introduced the idea that there are distinct modes in the way that individuals – researchers, practitioners, and policy-makers – perceive the science-policy interface. This typology has been explored subsequently on small samples of science-policy boundary workers (e.g., Hoppe, 2009). I developed this framework on a large sample of science and policy actors from the natural resource field. This work forms the conceptual basis Chapters IV and V. Briefly, convergers perceive high compatibility between science and policy. They are comfortable with the messiness and complexity of decision-making processes, and appreciate that science is one of many voices. Divergers perceive an inherent incompatibility between science and policy, driven by the antagonisms between scientifically-derived objective and empirical knowledge, and subjective social and political knowledge that emphasizes the importance of values, beliefs, and interests in the consideration of decisions (Hoppe, 2009). These two perspectives are not dichotomous, but should be seen as two ends of a spectrum on which one may characterize attitudes to the policy-making process, and the role of scientific evidence within that. This typology formed the basis of my research into the influence of values and attitudes on evidence utilization and research prioritization.

Chapter IV. A narrative policy approach to environmental conservation. Lawton and Rudd, Ambio 2014

During the literature review phase, and more strongly through qualitative analysis of interviews with policy actors in Part Two, it became clear that evidence influence on the policy process was strongly associated with the attitudes and perceptions of the individuals in charge. Political context was an important consideration, but so too, I suspected, were societal attitudes (Schwartz, 1992; Stern et al., 1999). Social psychology and policy analysis literature suggested that policy-orientated priorities are based on personal values and beliefs (Dietz and Stern, 1995; Sabatier and Jenkins-Smith, 1993). Our pre-existing values and beliefs act as a filter on the information we receive. They influence how we interpret the relevance of new information and its connectivity to issues of wider societal interest (Lord et al., 1979; Munro and Ditto, 1997). These societal attitudes were embodied in the personal beliefs of the individuals involved, in line with the Advocacy Coalition Framework (Sabatier and Jenkins-Smith, 1993, 1999). What was required was a set of tools that would identify individual’s attitudes and beliefs with relation to their perceptions of the science-policy interface.

Chapter IV is grounded within the Narrative Policy Framework (Jones and McBeth, 2010; Shanahan et al., 2011). It provides a review of the NPF as applied to my analysis of the Natural Environment White Paper in Chapter III. However, I include the chapter in Part Three because of its focus on attitudes to the science-policy interface. Chapter IV addresses the divergent perspective of much discourse in the conservation science community, and sought to highlight the limitations of the deficit model perspective through the lens of converger/diverger attitudes (Hoppe, 2009; Wittrock, 1991). I found that the logical distinctions theorized by Wittrock (1991) and subsequently tested by Hoppe (2009) were adaptable to discursive analysis as laid out in the Narrative Policy Framework (Jones and McBeth, 2010; Shanahan et al., 2011). I set out in detail what an NPF approach to account for evidence influence might look like. A range of methodological approaches are applied, including the use of preliminary analysis of policy settings, coding of narrative archetypes, strategic narratives and rhetorical devices, and attention to the currency of causal stories and metaphors. I explore the benefits of an NPF approach in comparison to the ACF in the conclusion to this thesis. In line with Leslie et al. (2013), I outline the ways in which a narrative approach to understanding the utilization of evidence may help conservation scientists to adjust the perspective on the role of policy context in research impact (Jones and McBeth, 2010; Shanahan et al., 2011).

The paper grounded its perspectives and discussion within the real-world example of the development of Ecosystem-based Management (EBM) in the UK. This led thematically from Part Two, and provided necessary grounding for the conceptual and methodological ideas developed therein. This led to some interesting discussion around the 'coupling' of ecosystem service narratives of economic evidence to EBM narratives of ecosystem value. By again applying the Cash et al. (2002) credibility-legitimacy-salience framework to this policy area, I hypothesized how strategies for increasing the relevance of one counter-narrative (for instance EBM) over another might risk losses of legitimacy and credibility with one's natural advocacy coalition base. Conversely, EBM counter-narratives that fail to provide salience for central government actors may risk the predominance of morals around the marketization of nature, with limited considerations for habitat connectivity and systems understanding (Lawton and Rudd, 2013).

Chapter V. Science-policy discourses and resource-management policy in the United States. Lawton, Rudd, and Fleishman, PLOSOne 2014

The conceptual work from Chapter IV provided a framework for exploring attitudes to science-policy interactions along converger/diverger lines. Chapter V tested and developed value scales using quantitative and qualitative approaches, developing questions that can be used to test for converger/diverger orientation going forward. I was presented with the opportunity to work with a pre-existing sample frame of policy-makers, government scientists, academics, and others from NGOs and private sectors in the US natural resource management sphere. There was clear need for a follow up of the original study that prioritized a list of research questions identified in a collaborative USA government-academic exercise (Fleishman et al., 2011; Rudd and Fleishman, 2014). That list of questions, the USA 'Top 40', was developed to reflect the needs of policy makers with regards to research on the management of biological diversity in the USA. Rudd and Fleishman's (2014) data found strong differences in research orientation among scientists and policy-makers in the USA, but did not explain the divergence in research orientation among latent classes and how or why scientists and policymakers within latent classes had similar research orientations (Rudd and Fleishman, 2014). This left a puzzle as to why significant differences in research priorities existed. This was an excellent opportunity to test the application of a converger/diverger attitude scale for science-policy attitudes (developed in Chapter IV) on a diverse range of policy actors in a specific geographical and substantive area.

Qualitative analysis of open-space responses from the initial survey suggested that an “in-depth probe of personal and professional beliefs and experience with the successful use of science in natural resource management and policymaking may shed further light on why research orientation differed among the survey respondents” (Rudd and Fleishman, 2014). I found evidence of a backlash against the research utilization agenda. Some argued that “scientists should primarily pursue discovery and problem solving in their areas of expertise” (ID237, interview, not reported in the text). Others criticized basic research as “several steps from policy relevance and meaningful in a really different way for decision-making” (ID216, interview, not reported in the text). As with research priorities, there were no significant explanatory covariates. I was hopeful that a more in-depth probe of personal and professional beliefs, and actual experience with the successful use of science in natural resource management and policy-making would shed further light on why research orientation differed among survey respondents.

The survey of scientists and policy-makers in the United States was designed to test whether differences in research priorities were better explained as a function of personal values (defined on the basis of Schwartz's theory of universal values) or professional attitudes. I classified attitudes about the interface between science and policy as converger (high compatibility between science and policy) or diverger (incompatibility between science and policy). I used latent-class cluster analysis to identify patterns of agreement or disagreement with these statements. Differences in professional or personal values, either alone or in combination, may help explain how individuals interpret novel information in the policy sphere (Lord et al., 1979; Munro and Ditto, 1997).

The results led to rejection of the hypothesis that there were no differences in attitudes about the interface between science and policy among USA scientists and policy-makers in our sample and the hypothesis that there were no differences in underlying values among respondents. Professional values – defined according to the converger/diverger scale - explained a greater proportion of the differences in attitudes of individuals working in the natural resource management field than personal values. Our results raise additional questions about the links between personal values and professional attitudes and the extent to which either affects priorities for research on management of natural resources. We also found indications that the personal importance of influence and impact may be motivated by altruistic urges to improve an external situation, rather than by self-enhancement. The potential ambiguity between the altruistic and egoistic motivations of influence and impact suggests that the scale of universal values does not distinguish reliably between personal and professional values. This may require modification of scale items to remove the dichotomous relationship it implies between self-enhancement and other-enhancement values (Stern et al., 1998). These questions may be worthwhile to incorporate into deliberative research-prioritization processes in the future

Conclusion

The papers submitted for this thesis are connected by a set of unifying themes. These include consideration of non-academic impact, and the role of contextual factors in research utilization, including but not restricted to the strategic use of evidence (Amara et al., 2004; Weiss, 1979); the application of public policy theories to the analysis of science-policy impact; the role of powerful individuals and groups in the policy process (Kingdon, 1995; Sabatier and Jenkins-Smith, 1999); the role of personal and professional beliefs in the cognitive uptake of new information (Dietz et al., 1998; Henry and Dietz, 2012; Lord et al., 1979); and the decline and ascendancy of perspectives on science-policy interface (Hoppe, 2009; Wittrock, 1991). The concluding chapter summarizes the contribution of this thesis to academic knowledge, accounts for the limitations of the research, and proposes areas for further research.

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Chapter I. Crossdisciplinary research contributions to the United Kingdom's National Ecosystem Assessment

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Abstract

To date the UK National Ecosystem Assessment (UKNEA) is the largest ecosystem service valuation project undertaken at the national scale. It is the result of combined efforts by natural scientists, economists, and social scientists from academic, private, government, and non-governmental organizations. We used a practical methodology to measure crossdisciplinary behavior in the UKNEA and examined the role of crossdisciplinary collaboration in a large-scale ecosystem assessment. We focused on the use of knowledge and techniques from other disciplines by individual research contributors. We assessed the success of the UKNEA against a framework of transaction costs and impact benefits associated with different levels of crossdisciplinary collaboration. Our results suggest that the UKNEA integrated knowledge more successfully between neighboring disciplines, but struggled to overcome barriers between natural and social science. The inclusion of policy-makers and practitioners brings optimal returns to investment in the research production process. This provided a pragmatic balance for an initial exercise but that may be insufficient for longer-term policy uptake and integration of natural and social science supporting the ecosystem approach at broad scales and in complex social-ecological systems.

Introduction

Modern environmental problems are complex. They are defined at the point at which they dissect human society (Cronon, 1992; Hajer, 1993) and influenced by evolving societal values. Various management options can have important social and economic effects, so a broad set of interest groups may have high stakes in environmental decisions (Funtowicz and Ravetz, 1993, 1994). No single scientific discipline can alone supply the knowledge needed to solve complex challenges (Carpenter et al., 2009; Liu et al., 2007; Reid et al., 2010).

An integrated approach to environmental decision-making is needed (Rotmans and Dowlatabadi, 1996; Toth and Hizsnyik, 1998) and should be informed by ecological and institutional context so that interventions consider human institutions and behavior (Folke et al., 2007; Young and Underdal, 1997). The integration of knowledge from beyond the traditional science disciplines, including that from actors outside academia and people directly affected by potential policy interventions, should be encouraged in decision-making processes that entail high risk decisions based on uncertain evidence (in line with post-normal science, see Funtowicz and Ravetz, 1993; Gibbons, 1994; Nowotny et al., 2001). Drawing input from across a range of sources should help ensure that socio-cultural considerations are given weight in societal decisions (Buscher and Wolmer, 2007). Such ideas have become the 'mantra of science policy' since the mid-1990s (Bruce et al., 2004; Metzger and Zare, 1999). However, the extent to which these ambitions are practical in application is so far underexplored in the literature.

The collaboration of scientists across disciplines is, however, complicated by differences in organizational cultures and underlying assumptions and approaches to knowledge production (Metzger and Zare, 1999). These differences are exacerbated when considering broader collaborations with individuals outside the scientific sector (Laniak et al., 2013). For instance, decision-makers in the private and public sectors may have biases towards quantifiable and monetizable data (Davies et al., 2000; Nutley et al., 2007). Excessively narrow discipline-bound research results may be inaccessible and create disconnects between the indicators measured by scientists and those that the public care about (Nahlik et al., 2012). Such shortcomings have prompted increasing interest in cross-cutting research that supports complex decision-making. Gradations of crossdisciplinary integration range from the parallel 'multidisciplinary' work of two or more disciplines, to the integration of diverse disciplinary data and methods in 'interdisciplinary' research, to the epistemological synthesis aspired to by 'transdisciplinary' research (Committee on Facilitating Interdisciplinary Research, 2005; Rosenfield, 1992; Klein, 2004).

The translation of ecosystem structure and function into ecosystem services and the measurable benefits they provide humans is one field that requires such crossdisciplinary approaches (Daily et al., 2009; Kremen, 2005; Scheffer et al., 2000). Ecosystem services have come to take a central place in environmental management discourse (Gómez-Baggethun et al., 2010). The Millennium Ecosystem Assessment (MEA) was the first large-scale (>1,360 experts worldwide) assessment to adopt the ecosystem service approach in its appraisal of the condition and trends in the world's ecosystems and the services they provide (Mace et al., 2005). The emerging ecosystem service approach thus offers a valuable opportunity to examine the degree to which crossdisciplinary research is being, or could be, used in environmental management.

The UK National Ecosystem Assessment (UKNEA) was the UK's response to the MEA (UKNEA, 2011). The UKNEA's first phase was commissioned by the UK Department for Environment, Food and Rural Affairs (Defra), national environment agencies, the Natural Environment Research Council (NERC), and the Economics and Social Research Council (ESRC). The UKNEA was led by a 27-member expert panel, consisting of natural scientists, economists, social scientists, and policy-makers; the panel provided the UKNEA's technical focal areas, key messages, and approved the content of the final chapters. The UKNEA structure consisted of 27 chapters, split broadly between individual habitats and ecosystem services, economic, health and well-being values, and scenarios and response options. Each chapter was led by one or more coordinating authors and assembled by lead and contributing authors. The UKNEA tracked the direction of change over the last sixty years for a range of indicators of habitats and ecosystem services. Scenarios for ecosystem service trends were calculated using population, climate, and resource use forecasts.

The outputs from the UKNEA are currently being incorporated into central government decision-making. The UK Treasury (H. M. Treasury, 2012) and Office of National Statistics accounting (Office of National Statistics, 2012) are incorporating environmental valuation into national project accounting and appraisal. The UKNEA not only provides a 'key evidence base' for these decisions (H. M. Treasury, 2012, para. A.1), but is directly incorporated through 'the ecosystem services framework' as a key step in defining wider environmental effects (H. M. Treasury, 2012, para. 4.18). The second phase of the UKNEA will expand its focus to cultural ecosystem services that were not fully captured in the first phase (UKNEA, 2012).

One of the project's goals was to "foster better interdisciplinary cooperation between natural and social scientists to assist in strengthening policy-making in order to ensure effective management of the environment and ecosystem services in the future" (UKNEA, 2011, p. 1.3). However, beyond general calls, this was never expanded into an explicit framework for research practice. We asked two questions regarding the nature and extent of crossdisciplinary collaboration in the UKNEA. First, how can disciplinary integration in a large ecosystem assessment be measured? Second, what level of disciplinary research integration did the UKNEA promote? Third, what is disciplinary integration expected to achieve, and what did it achieve in this case. Answering these questions, we believe, can help build understanding regarding crossdisciplinary processes in future ecosystem assessments and aid in quantifying crossdisciplinary collaboration for planning and evaluation purposes. Our focus was at the level of individual UKNEA chapter contributors. That facilitated subsequent analysis of integration of broader disciplinary groups and chapters in the overall assessment.

Theoretical background

Defining crossdisciplinarity

Large-scale ecosystem assessments provide valuable case studies on scientific collaboration across (and beyond) a broad range of disciplines. As Porter et al. (2007, p. 117) assert, "integration is the key concept here – distinguishing the 'seamless cloth' of [interdisciplinary research] from the 'patchwork quilt' of multidisciplinary research, and the more restricted focus of disciplinary research." Crossdisciplinary integration is normally presented at the theoretical level in terms of gradations. For instance, Rosenfield (1992) presents a continuum of unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary research. Multidisciplinarity is the most basic level of disciplinary integration, where teams work separately and in parallel within their own disciplinary bases. At a moderate level of integration, interdisciplinary researchers work jointly with more collaboration between disciplines but still with a clearly delineated disciplinary base. At its most integrated, transdisciplinary research creates a shared conceptual framework and synthesizes discipline-specific theories (Rosenfield, 1992). Aboelela et al. (2007) synthesized crossdisciplinarity gradations, drawing on the work of Rosenfield (1992), Klein (1996), and Lattuca (2001) (Table 1).

As noted by Stokols et al. (2008, p. s79) "the distinctions among unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary forms of scientific collaboration are directly relevant to the development of criteria for gauging the success of team science initiatives" in terms of collaboration and research impact. We note that the definition of transdisciplinarity can be expanded beyond Rosenfeld's to include the integration of researchers and extra-scientific actors in research from its earliest stages (Funtowicz and Ravetz, 1993; Gibbons, 1994). This integrative element of collaboration between science and society is the difference between ‘shallow’ and full definitions of transdisciplinarity; full transdisciplinarity requires that “all parties involved participate in the problem transformation” (Jahn et al., 2012, p. 5). Shallow transdisciplinarity that seeks synthesis between disciplines at the conceptual level (Lawrence and Després, 2004; Nicolescu, 2006; Wickson et al., 2006). Full transdicsiplinary integration is seen to include the participation and inclusion of policy and practitioner actors at every stage of the research production process (Lang et al., 2012; Nowotny et al., 2001; Stokols, 2006) that may increase the salience and impact of research beyond academic audiences.

Table 1 – Characteristics of multidisciplinary, interdisciplinary, and transdisciplinary research (adapted from Aboelela et al., 2007)

	Multi-disciplinary	Inter-disciplinary	Trans-disciplinary (shallow)	Trans- disciplinary (full)
Participants	Two or more disciplines	Two or more distinct academic fields	Two or more distinct academic fields.	Incorporation of non-scientific actors from earliest stages
Problem Definition	Same question but different approaches	Described/ defined in language of at least two fields, using multiple or intersecting models	Stated in new language or theory that is broader than any one discipline	Problem jointly defined by policy and expert partners
Research Style	Parallel research structures	Drawn from more than one, with multiple data sources and varying analysis of same data	Fully synthesized methods, may result in new field	Synthesis of existing knowledge with policy recommendations/ solutions
Presentation of findings	Separate publications by participants from each discipline	Shared publications with language intelligible to all involved fields	Shared publications probably using at least some new language developed for translation across traditional lines	Shared publications with policy and academic audience

Measuring crossdisciplinarity

Many bibliometric studies have applied a range of techniques for measuring crossdisciplinary citations (Porter and Rafols, 2009; Porter et al., 2007). Disciplinary variation may be measured through references within a paper or by publications in disciplinary categories of varying disciplinary distance (Morillo et al., 2003; Porter and Chubin, 1985; Rafols and Meyer, 2007). Citation analysis was combined in some papers with network analysis of the coherence and diversity of citations within disciplines and subdisciplines (Rafols and Meyer, 2007; Van Raan, 2000). Bibliometric analysis allows categorization of scientific disciplines (Bordons et al., 1999; Morillo et al., 2003; Rafols and Meyer, 2007). Disciplinary boundaries are commonly defined using journal disciplinary categories (Institute for Scientific Information or Global Map of Science) and provide useful insights into the range of scientific disciplines from which a specific research output draws.

Multi-dimensional measures that combine bibliometrics with compositional analysis of researcher disciplines and qualitative data have also been developed. Quantitative measures of researchers' participation in projects by their discipline and subgroups provide indicators of disciplinary integration in day-to-day working practices (Bordons et al., 1999; Evely et al., 2010; Stokols et al., 2008). This can provide a measure of interpersonal collaboration in research production and was further extended to include communication behavior and interactions at the interpersonal level (Bordons et al., 1999). In a similar vein, Sanz-Menendez et al (2001) developed multi-dimensional methods that combined bibliometric analysis of subject diversity with compositional analysis of research groups, alongside qualitative survey data on researchers' use of knowledge from other disciplines as measure of their 'knowledge use and borrowing' behavior.

Case study approaches track antecedents, processes, and outcomes of 'team science' initiatives through survey, interview, observational, and archival measures (Stokols et al., 2003, 2008). Science initiatives are seen as "strongly influenced by social and interpersonal processes", such as collaborative styles and behaviors, interpersonal conflicts, and negotiation strategies (Stokols et al., 2008, p. s81). Crossdisciplinary indicators were founded in project goal evaluation, and underlain by distinctions between unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary forms of scientific collaboration (Rosenfield, 1992). Crossdisciplinary research effectiveness depended on context-specific and project-specific specification of dimensions and criteria (size, structure, composition) and, importantly, objectives of the program (Stokols et al., 2008). Recent advances in this field have focused further on how individual-level interpersonal processes influence collaborative effectiveness (Mâsse et al., 2008; Trochim et al., 2008).

Qualitative data on disciplinary integration, data-collection methods, and researcher collaboration can also provide valuable information on collaboration (Evely et al., 2010). While qualitative analysis can be difficult to integrate with quantitative data (Bryman, 2007), qualitative survey results have provided important information on how cross-disciplinary barriers acted as barriers to scientific collaboration (Stokols et al., 2003; Trochim et al., 2008). Typologies of crossdisciplinary barriers (Jacobs and Amos, 2010), and models of project characteristics like leadership in facilitating or obstructing disciplinary integration, may provide a guide for indicators to be used in qualitative analysis (Gray, 2008; Pennington, 2008).

Challenges of evaluating the NEA

Measuring crossdisciplinary collaboration presents challenges. First, gradations of disciplinary integration have multiple definitions (see Aboelela et al., 2007). Second, units of analysis, metrics, and methods of measurement vary. In the case of the UKNEA, we were concerned that bibliometric analysis alone would not provide adequate information about the role of collaboration at the personal, procedural, and institutional level (Wagner et al., 2011). The structure of the UKNEA, where different working groups produced chapter-based outputs, also meant analysis of research output at the project level would lose crucial information on collaboration and interaction between the working groups.

For the UKNEA project we were thus drawn to combining compositional and observational methods with qualitative techniques (Evely et al., 2010; Pohl, 2005; Sanz-Menéndez et al., 2001). Qualitative approaches may introduce 'demand characteristic bias' where respondents form interpretations of question purpose (Orne, 2009), leading respondents to over or understate crossdisciplinary behavior. There is also danger that definitions of crossdisciplinarity differ between researcher and interviewees, and between interviewees (Sanz-Menéndez et al., 2001). One possible way to address this challenge is to transpose bibliometric measures of diversity between citations onto analysis of individual collaboration. This would require classification of individual respondents by discipline. Bibliometric analysis can readily be organized by existing disciplinary categorization of journals (Morillo et al., 2003; Alan Porter et al., 2007; Rafols and Meyer, 2007). Classifying individual researchers by discipline is less clear. Guidance may be sought from Pohl (2005) who cleaved an analysis into additive and interrelating collaboration between natural and social scientists.

Finally, evaluation of research collaboration should be developed specific to characteristics and objectives of the program (Stokols et al., 2008). Assessment should identify "the highest-priority goals and corresponding criteria of success for any given program" as the benchmark (Stokols et al., 2008, p. s80). Where this is not explicitly stated, objectives should be framed within existing assessment frameworks.

Integrated Environmental Assessment

Ultimately, we decided to frame our UKNEA analysis within integrated environmental assessment (IEA) literature (Laniak et al., 2013; Rotmans and Dowlatabadi, 1996; Toth and Hizsnyik, 1998). Ecosystem assessment offers fresh challenges to assessing processes and feedbacks for a range of biophysical and social systems (Carpenter et al., 2009). The primary challenge of merging knowledge domains into "coherent and appropriately complex representations of the relevant system" (Laniak et al., 2013, p. 8) should be approached by three criteria: integration should be greater than the sum of the disciplinary parts; disciplines share equal footing; and problem structuring and analysis operate at equal footing (Tol and Vellinga, 1998). Integrated assessment modeling assumes the 'added value' of disciplinary integration: synergism, new synthesis insights, and attention on problem causality (Rotmans and Dowlatabadi, 1996), but this is determined by the ability of a range of scientific disciplines to cooperate (Tol and Vellinga, 1998).

How much crossdisciplinarity is needed?

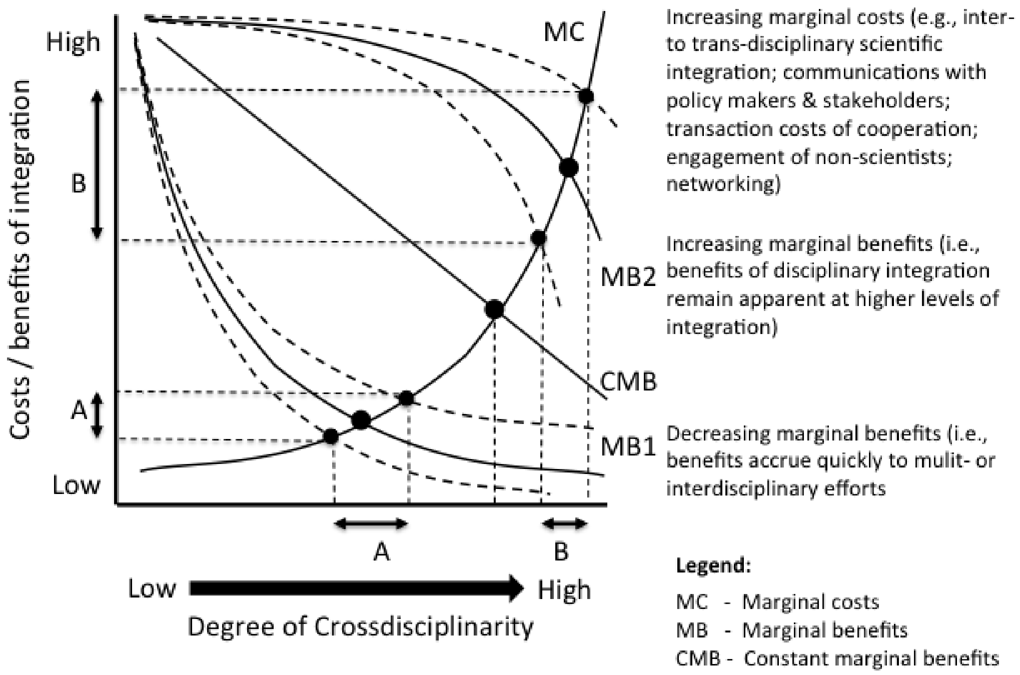
The ambition for the UKNEA to be a comprehensive database of natural capital resources, ecosystem services, and trends in resource depletion and habitat degradation (personal communication, UKNEA Co-Chair Professor Watson) must prioritize the integration of scientific knowledge across the 'grand' disciplinary boundaries of natural and social science. It is, however, clear that facilitating the integration of knowledge and methodologies from the natural sciences, social sciences, and non-scientific fields is costly in terms of time and resources (Jacobs and Amos, 2010). Findings from crossdisciplinary network analysis suggest that larger networks of researchers may experience economies of scale up to a certain point. After that point, the "burden of collaboration becomes too great, and the costs of collaborating in terms of effort and time exceed the benefits" (Rigby and Edler, 2005, p. 792). We represent this relationship as a marginal cost curve (MC, Fig. 1). At the lowest level of disciplinary integration (mono- and multidisciplinarity, on the *x*-axis), transaction costs, in the form of facilitating arrangements, building social capital, and efforts to develop new methodologies or epistemologies, are likely relatively low (Fig. 1, region A). To achieve true transdisciplinarity, the costs of research integration may rise rapidly (Fig. 1, region B).

Efforts to integrate across disciplinary boundaries will depend on the relative value-added of integration and on the ability of scientists across disciplines to engage and cooperate. We illustrate two possibilities in Figure 1. In line MB1, we see decreasing returns to crossdisciplinary research, where relatively rapid gains from multidisciplinary or interdisciplinary research, slow as more complete integration is attempted. On this line, the greatest benefits accrue at lower levels of disciplinary integration. This may be because there is little call for disciplinary integration, meaning that mono- or multi-disciplinary research is adequate to the task. MB1 intersects with the marginal cost line once these benefits have accrued (Region A). This would imply relatively lower levels of optimal investment. Beyond this point, the increasing marginal costs of disciplinary integration, such as transaction costs of cooperation; engagement of non-scientists; networking, outweigh the benefits of crossdisciplinary integration for research production.

In MB2, returns to scale are reversed. Increasing returns mean that the benefits of disciplinary integration remain apparent at higher levels of integration (Figure 1, region B). As MB2 intersects with the marginal cost line at in the region of transdisciplinary research, the benefits of disciplinary interaction continue to outweigh the costs at higher levels of disciplinary integration. As with MB1, there is important variability built into the marginal benefit lines (dotted lines). For example, higher-level transdisciplinarity can be defined as shallow and full. Shallow transdisciplinarity, which involves the complex integration of academic disciplines at the epistemological level, sees marginal benefits accrue more slowly at the transdisciplinary level. This means that the costs of shallow transdisciplinary integration between different epistemologies and methods outweigh the benefits to the research project (lower dotted line of MB2). Full transdisciplinarity which involves the inclusion of non-academic experts, especially policy-makers and practitioners, sees efforts in this region continue to yield increased marginal benefits before intersecting with the MC line (upper dotted line of MB2). This is an important distinction, because it indicates that efforts to cross the divide between science and policy, rather than between disciplines, yields greater marginal returns, and therefore has a higher threshold before the marginal costs of higher disciplinary integration become apparent.

The uncertainty associated with those benefits implies a potentially wide range of ‘optimal’ investments in crossdisciplinary collaborations. While it is beyond the scope of this analysis to analyze the costs and benefits of the UKNEA, we note that the high costs of national or international assessments require significant scientific and policy impact returns to justify their societal investment; this will be a challenge for future researchers. However, the diffuse impact of knowledge created in this way may have more long-term benefits that may be difficult to quantify and could be missed in short-term assessments of crossdisciplinary research effectiveness (Amara et al., 2004; Beyer, 1997; Weiss, 1979). We set to test this framework against the evidence collected from interviews with actors involved in the development of the UKNEA.

Figure 1 – Conceptual framework for assessing the economically efficient level of investment in crossdisciplinary research



Material and Methods

Data collection

We developed a structured survey for individuals who participated in the development of the UKNEA. The survey questions were in four sections. Section 1 asked for self-reported data on respondents' disciplinary training. This was supplemented, when necessary, with supplemental online CV information. We collected self-reported data on respondents'roles and input to the UKNEA, including the topics and chapter each respondent worked on. Section 2 asked respondents about their use of knowledge from other disciplines. It asked which one form of information outside of the respondent's own area of expertise was most commonly sought. Options included the main disciplines from the natural and social sciences, as well as non-scientific policy and technical evidence. Section 3 asked respondents which type of organization or individual was most important for supplying outside expertise. We used options based on existing research-policy intermediary typologies (Clark, 2007). Section 4 was comprised of a series of open-end questions on established crossdisciplinary markers: disciplinary training; collaboration; integration; leadership; and barriers to integration (Trochim et al., 2008).

Sample

The total population of contributors to all 27 UKNEA chapters consisted of over 350 experts. We drew our sample from all coordinating and lead authors, and for those chapters with no lead authors, 30% of total contributing authors. Contributing authors were generally less involved in the process than lead authors so were only included where the total number of lead authors was <5. Our total sample consisted of 206 individuals. The internet survey was distributed through a gatekeeper, Professor Steve Albon (UKNEA Co-Chair), in July 2011.

Measurement of disciplinary integration

Our approach to measuring disciplinary integration on the UKNEA followed a multi-dimensional method. This consisted of compositional analysis of collaborative teams within the UKNEA chapter structure (Bordons et al., 1999; Stokols et al., 2008), combined with quantitative questionnaires on research usage at the individual level (Evely et al., 2010; Sanz-Menéndez et al., 2001; Trochim et al., 2008). We structured qualitative analysis within case study methodologies of 'markers' and antecedent conditions for disciplinary integration (Stokols et al., 2008; Trochim et al., 2008).

We defined individual-level analysis of disciplinary collaboration as 'expertise-seeking behavior.' We asked respondents about their "use of knowledge and techniques from other disciplines or fields" (Sanz-Menéndez et al., 2001, p. 52). We related self-reported data on the use of knowledge and techniques with respondent disciplinary backgrounds. The aim was to develop an "empirical measure of knowledge use and borrowing" in researcher behavior (Sanz-Menéndez et al., 2001, p. 52). Self-reporting demand-characteristic bias was reduced by avoiding reference to crossdisciplinarity in this section. Instead, we classified respondent disciplinary background independently through demographic survey data, supplemented by web research where necessary. We recorded expertise-seeking behavior against the disciplinary background of the respondent. It was also hoped that this would bypass problems caused by different understandings of crossdisciplinarity between respondent and researcher (identified by Sanz-Menéndez et al., 2001).

We registered collaboration between scientists from different disciplines (Bordons et al., 1999; Morillo et al., 2003). Interdisciplinarity may be measured between within the science disciplines (Porter and Rafols, 2009; Rafols and Meyer, 2007) (for instance between physics, medicine, neuroscience etc.), or across 'grand categories' of natural and social science (Porter and Chubin, 1985). Porter and Rafols (2009) found that even within the sciences, citation-based interdisciplinatity tended to occur mainly within neighboring disciplines. We focused on measuring crossdisciplinarity and its challenges across the broader natural/social science divide. We considered this research focus appropriate for ecosystem assessment-type projects located at the frontier of socio-ecological problem-solving (Carpenter et al., 2009).

We first grouped researchers according to two broad disciplinary areas: social science (including humanities), and others (see Morillo et al., 2003). We subsequently divided the other group between natural science and other disciplines (e.g., engineering). There is theoretical acceptance of the difference between those disciplines that study natural processes and those that study of human societies and social patterns (Klein, 1990)[1]. Nevertheless, the shifting nature of scientific and non-scientific careers, particularly in the environmental field, means that the interface between natural and social science is becoming less clear. For this reason we included trained natural scientists working in sustainability science within a general social science and interdisciplinary group (GSSI) in place of social science. We recognize, however, that this was to some extent arbitrarily defined.

Research group, or team-level analysis was set at the chapter-level. In line with Sanz Mendendez et al. (2001), research team composition was measured through: disciplinary diversity of team members (disciplinary composition; see also Stokols et al., 2008), and; qualitative appreciation of the degree of crossdisciplinarity within teams. We divided analysis into working groups around chapters. Chapters were divided between habitat and ecosystem service types, identification of trends, and scenarios for policy recommendations. We applied two levels of measurement to researcher chapter-work. Compositional analysis of total researchers working on the chapter was performed by assigning broad disciplinary background (natural science; GSSI; other e.g. administrative, engineering) to all researchers listed as chapter authors through web-research. Second, we grouped survey respondents by self-reported data on chapter involvement. Individual-level data on expertise-seeking behavior was scaled up to the chapter level.

Following Trochim el al's (2008) qualitative approach to 'key markers of crossdisciplinarity', our survey included open-end questions on disciplinary collaboration, disciplinary integration, and barriers. Responses were coded using the Atlas.ti software package (www.atlasti.com). Coding focused on antecedent processes of crossdisciplinary

[1] It should be noted that two styles of social science have been delineated elsewhere. The descriptive paradigm refers to research that analyses social systems in terms of natural science metaphors (e.g., in terms of mass balance, thermodynamics, or stocks and flows). In contrast, the interpretative approach refers to the analysis of the values, meaning, and motivation of human agents (see Rayner and Malone, 1998, p. 37).

collaboration (in line with "team science" techniques; see Stokols et al., 2003, 2008). Prior codes were applied from established crossdisciplinary markers: disciplinary training or facilitating arrangements; collaboration; integration; and leadership (Trochim et al., 2008). We also derived new codes from the data (Gibbs, 2002). Barriers to crossdisciplinary integration were coded following Jacobs and Amos' (2010) typology of disciplinary barriers: linguistic; methodological; and procedural. To provide further context for the UKNEA second stage development process, we also interviewed UKNEA Co-Chair Sir Robert Watson in the autumn of 2012.

We combined individual and chapter-level analysis with qualitative conditions to classify disciplinary integration of the project as a whole. Following Stokols et al. (2008), we classified project crossdisciplinarity as either unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. This provided a low-to-high scale of disciplinary integration at the UKNEA project level (Table 2). We adopted a broad definition of transdisciplinarity to include research activities that both exhibited synthesis at the level of disciplinary methodologies and epistemologies, and integrated policy and stakeholder actors from the problem definition stage.

Table 2 – Scale of disciplinary integration at the chapter-level

Disciplinary composition	Expertise-seeking behavior	Level
One dominant discipline	Interdisciplinary	Low
One dominant discipline	Extreme Interdisciplinary	Medium
Multiple disciplines	Interdisciplinary	Medium-High
Multiple disciplines	Extreme Interdisciplinary	High

Results

Survey results

Survey responses

A total of 78 of the 206 (38%) coordinating, lead, and selected contributing UKNEA authors completed surveys. We believe that this was a satisfactory return considering that many respondents worked in high-demand policy areas, university positions, and private sector consultancies, and that the survey was distributed over summer. The mean number of questionnaires returned per chapter was five.

Disciplinary composition

We determined the percentage of respondents from natural sciences (56%); economics (10%); self-defined interdisciplinary (10%); policy (8%); and social sciences (5%) using self-reported data on disciplinary training. We compared disciplinary background of the sample with that of all UKNEA authors (developed from web-based research) and found no significant difference (x^2 = 0.201, df=7, $p < 0.05$). To assist analysis, we grouped respondents into disciplinary groups of natural science (56% of sample), GSSI (34%), other (7%), and unknown (3%).

Expertise-seeking behavior of authors

Following Sanz-Menendez et al's (2001) empirical measure of the knowledge use and borrowing, we found that scientific advice was most commonly requested by all disciplinary backgrounds (56%). The next most important forms of outside expertise requested were economic (21%) and policy advice (13%) (Table 3). Over 60% of our respondents sought advice from scientists in academia. This was notably higher than those seeking expertise in-house (17%) or those seeking advice from sources working in government or civil service departments (10%).

Table 3 – Disciplinary networking behavior of respondents (*n*) by general disciplinary background

Disciplinary source of expertise requested by respondent	GSSI respondents	Natural science respondents	Other disciplines	Total
Natural science	13	27	5	45
Economics	7	7	3	17
Social science	4	2	0	6
Policy	2	7	1	10
Technical	0	1	1	2
Total	26	44	10	80

We classified collaboration between: a) 'neighbor' disciplines (Porter and Chubin, 1985; Porter and Rafols, 2009), and; b) across the natural/social science boundary (Morillo et al., 2003; Pohl, 2005) (Table 3). We found that 13 out of 26 GSSI respondents (50%) and 17 of 44 natural scientists (39%) sought expertise across 'grand categories.' Combined, 43% (30 of 70) of natural science and GSSI contributors to the UKNEA displayed expertise-seeking behavior that crossed grand categories. There was no significant difference between expertise-seeking from neighboring disciplines and across the natural/social science boundary.

Expertise-seeking among neighboring disciplines was most prevalent among natural scientists, with 61% (27 of 44). The GSSI group was split 50/50. Cross-boundary disciplinary expertise-seeking was significantly different between natural science and GSSI respondents ($p = 0.043$).

Table 4 – Compositional analysis of author disciplinary background by chapter

Chapter	Disciplinary Composition			Collaboration	
	% Natural Science	% GSSI	% Other	% Neighbor	% Boundary
1. Introduction	50	50	0	80	20
2.Conceptual framework & methodology	50	50	0	50	50
3. Drivers of change in ecosystems & ecosystem services	75	0	25	100	0
4. Biodiversity in the context of ecosystem services	90	10	0	67	33
5. Mountains, moorlands and heaths	100	0	0	56	44
6. Semi-natural grasslands	100	0	0	33	67
7. Enclosed farmland	100	0	0	50	50
8. Woodlands	100	0	0	33	67
9. Freshwaters: openwaters, wetlands and floodplains	100	0	0	56	44
10. Urban	60	40	0	33	67
11. Coastal margins	100	0	0	71	29
12. Marine	100	0	0	100	0
13. Supporting services	100	0	0	67	33
14. Regulating services	100	0	0	60	40
15. Provisioning services	100	0	0	50	50
16. Cultural services	20	80	0	60	40
17. Status and changes in ecosystems and their services to society: England	100	0	0	67	33
18. Status and changes in ecosystems and their services to society: northern Ireland	100	0	0	50	50
19. Status and changes in ecosystems and their services to society: Scotland	100	0	0	50	50
20. Status and changes in ecosystems and their services to society: Wales	90	10	0	63	38
21. UK dependence on non-UK ecosystem services	0	100	0	0	100
22. Economic values from ecosystems	20	80	0	22	78

23. Health values from ecosystems	10	90	0	33	67
24. Shared values for the contributions ecosystem services make to human well-being	0	100	0	100	0
25. Scenarios: development of storylines and analysis of outcomes	60	0	40	100	0
26. Valuing changes in ecosystem services: scenario analysis	50	50	0	50	50
27. Response options	50	50	0	NA	NA

Research groups: UKNEA chapters

We applied two levels of measurement to researchers' chapter work. First, in compositional analysis of total researchers working on the chapter (Table 4, columns 2-4), we found that 16 of 27 chapters were composed of >67% natural scientists. Thirteen of those chapters were 100% composed by natural scientists. These included all habitat-focused data chapters, with the exception of urban habitats. Three of the four ecosystem service chapters (supporting, regulating, and provisioning) were also 100% composed of natural scientists. The cultural services chapter was 80% composed of GSSI researchers.

Secondly, we aggregated individual-level data on expertise-seeking behavior between neighboring disciplines and across boundaries to the chapter level (Table 4, columns 5-6). Expertise-seeking behavior was broadly split between neighboring disciplines and across disciplinary boundaries. Eight chapters contained >67% authors collaborating with neighboring disciplines. Four chapters contained >67% collaborating across the natural/social science boundary. We found no significant relationship between disciplinary composition of chapters and expertise-seeking behavior.

Antecedent conditions

Forty-six of 78 respondents completed one or more open-ended qualitative responses. Results were divided according to crossdisciplinary success markers.

Collaboration

The benefits of disciplinary collaboration were well-represented in qualitative responses. "Having those familiar with diverse fields already attached to the group" (R33-OD) was important[2]. The sense was the scope of problems and level of technical detail required "simply would not have been known to a uni-disciplinary group" (R47-GSSI). For some, understanding and managing ecosystem services was "inherently interdisciplinary" (R12-GSSI; R32-NS; R48-NS). For others, integration went beyond academia: "the whole purpose of the ecosystems approach is to link living ecosystems with people, and from a science perspective to 'force' a heightened degree of integration" (R55-NS).

Criticisms voiced of disciplinary collaboration ranged from the personal - "I really did not work with many outside my discipline" (R8-NS) – to the procedural - "a chain of experts passing information… [is] very limited interdisciplinary working" (R4-NS). Causes

[2] We refer to respondents by number (e.g., R33) and disciplinary classifications by letter (e.g., OD = other discipline, GSSI = general social science and interdisciplinary, NS = natural science).

of low disciplinary integration included problems at the working-group chapter-level with “narrow focus” (R49-NS), and “lack of communication between chapters” (R49-NS).

Integration

Project integration was identified on two levels: user-groups and expert (Laniak et al., 2013). Respondents attested to the integration of policy and stakeholder actors during the problem definition stage of the project. This extended to the individual author-level that “tried to ensure that the questions asked in the UKNEA were driven by the end-user” (R67-NS). The UKNEA went further, integrating “end-users from agencies and NGOs” throughout the authorship process. This both recognized the “greater impact of…transdisciplinary approaches (R51-NS), and ensured “by default” the integration of authors with problem-focused, “interdisciplinary day jobs” (R51-NS).

Training

Pohl (2005) found that researchers often need several years of collaboration “to become acquainted with and develop respect for the other ‘culture’ before they will be able to develop joint concepts” (Pohl, 2005, p. 1175). Training and facilitating arrangements may speed this process. We divided coding of training issues into categories. The first, facilitating training, involved “setting up institutions, workshops, projects that emphasis the human-scale dialogues of interdisciplinarity” (R7-NS). These included “substantial shared discussion around the conceptual framework” (R98-NS), “capacity-building workshops”, and “development of indicators for interdisciplinarity (rather than multidisciplinary) working” (R51-NS). The value of “face-to-face” contact time with researchers from other disciplines at “informal discussion groups to review concepts in [cross]disciplinarity and working practices” (R69-NS) was emphasized. The most cited barrier to training was limited time (R59-NS) and insufficient resources to facilitate meetings (R89-NS).

Secondly, ‘individual training needs’ emphasized the value of having researchers “trained to be cross disciplined…as translators” (R73-NS). Key interdisciplinary researchers with “'interdisciplinary' skills and knowledge sets” (R49-NS) were found to be valuable to crossdisciplinary collaboration.

Leadership

Gray (2008) conceptualized three forms of leadership. Cognitive leadership refers to conceptual direction from above: “leadership that is interdisciplinary from the start promoting interdisciplinary working” (R62-NS). For instance, in place of project leadership "dominated by one discipline" (R24-GSSI), disciplinary diversity in project leadership was seen as preferable, with "at least one co-chair having a stronger socio-economic background" (R89-NS).

Structural leadership refers to defining objectives, recruiting expertise, project accountability and management (Gray, 2008). Disciplinary integration, like other aspects of project management, "requires clear definitions to achieve a joint goal" (R51-NS). "Absence of process alignment (of goals, discourse formation)" presented a "major barrier to genuine interdisciplinary working" (R62-NS). This was attributed to issues of resource allocation, time constraints and project size. The result was that project leadership struggled to operationalize "an interdisciplinary trajectory" (R62-NS).

Failure in procedural leadership was identified in the restrictive effects of chapter structure. This was attributed by some to "a general attitude that interdisciplinary issues are too difficult and must be reduced to disciplinary-sized pieces" (R49-NS). As inferred by this comment, individual-level barriers to integration at the project-level were present throughout the project, but it was the failure of the leadership to encourage an alternative narrative that caused barriers.

Leadership may be exercised at multiple levels. At the chapter-level, coordinating lead authors were responsible for: "facilitating exchange" between chapters through connections with other lead authors (R51-NS), and; "inter-institutional" procedural leadership (R8-NS), particularly through the operationalization of networks and set of expert contacts from other disciplines.

Social capital

Social capital contributes to crossdisciplinarity on two levels. Researchers bring their own stock of social capital to a project, in the form of personal contacts and 'ecosystems of expertise' on which to call (Burt, 1997; Oh et al., 2004). Researchers also build new networks of interactions on the project. Crossdisciplinary interaction may occur within chapter teams (R68-NS), and across chapters. Networks forged between chapters bring added value to the project. Inter-project interactions can be facilitated by "investing in networks and dialogue creation to facilitate flows" (R7-NS), signposting "knowing who to go to" (R80-NS).

Barriers: linguistic

Barriers to crossdisciplinary collaboration were divided between linguistic, methodological, and cultural factors. The most prevalent barrier cited related to how language differed among disciplines, including how individuals from different disciplines had different understandings of the same specialist terminology. The difficulty of achieving "a common language" was especially strong across the natural/social science boundary, such as "between ecologists and economists" (R12-GSSI). This was partly driven by "different vocabularies, outlooks, and doctrines [of] social versus natural scientists" (R10-GSSI). Examples included the use of "different terms (resilience, persistence, functioning)…different conceptual approaches…different philosophical perspectives (utilitarian versus other value notions)… [and] different approaches to evidence" (R14-GSSI).

Barriers: methodological

Barriers were also attributed to the dominance of some disciplines over other. A number of respondents referred to "protectionism of ideas" (R46-OD), "disciplinary rivalry" (R50-GSSI), over-powerful disciplines (variously, economics or biology), or the "marginalization of the social sciences" (R62-GSSI). The risk is of methodological "orthodoxy" which meant the UKNEA was restricted to "boundaries imposed by the disciplinary experts." The result, according to another, was that "subject areas and delimitations were chosen which suited some disciplines but were not necessary as relevant to the discipline concerned; this can distort outcomes" (R77-NS). The UKNEA Co-Chair also suggested that disciplinary barriers in the UKNEA arose between social scientists and economists. "The biggest challenge is not between economists and natural scientists, it's between the non-economist social researchers…" (personal communication, UKNEA Co-Chair Professor Watson).

It is important to note that methodological 'hegemony' could also be seen as a good thing from the perspective of policy impact. "It allowed a particular viewpoint to be advanced which is what policy audiences want. Trying to accommodate a plurality of approaches would have probably weakened the result and impact" (R77-NS). Methodological hegemony may allow a simple, single viewpoint to be advanced to policy-makers, which simplifies the knowledge communication process. Multiple epistemological and methodological inputs, in contrast, may heighten the sense of fracture and disagreement, giving the impression of a 'wicked' policy problem area (Sarewitz, 2004).

Barriers: procedural

Finally, some comments identified the size of UKNEA as a barrier. One respondent, for instance, argued the UKNEA was "too broad in scope… to foster a good interdisciplinary approach" (R36-NS). Another complained of a "general atmosphere of working towards the delivery of a monster before a certain date" (R62-GSSI). One respondent identified the risk that "in bigger projects, teams get divided into work packages, which tend not to be very interdisciplinary, and the silo-ization of research is actually reinforced" (R78-GSSI). In a similar vein, another respondent (R96-NS) asserted that "interdisciplinary work has high transaction costs and takes time".

Discussion

Measuring crossdisciplinary success

National-scale ecosystem assessments rely on the combined efforts of experts from a range of disciplines both for the substantive problem area they cover, and the scale and size of the dataset assembled (Carpenter et al., 2009). The primary challenge is merging knowledge domains into "coherent and appropriately complex representations of the relevant system" (Laniak et al., 2013, p. 8). As ecosystem assessments in the future include more socio-economic and cultural data (e.g., UKNEA, 2012), efforts to facilitate and measure crossdisciplinarity at the research project level will become more important. While the value of collaboration between neighboring disciplines is important for integrated environmental assessment (Porter and Rafols, 2009; Toth and Hizsnyik, 1998), these may be offset by the costs of overcoming procedural and conceptual disciplinary barriers between disciplines (Stock and Burton, 2011). Our research aimed to capture the level of crossdisciplinarity observable on the UKNEA. The focus of our study was on individual-level collaborative behavior across the natural/social science divide, and research group disciplinary composition at the chapter-level.

At the individual authors' level, our results suggested great variability across the project. Expertise-seeking behavior was most common among neighboring disciplines. Networking tended to take place within academia or in-house, with a much smaller number of respondents seeking advice from government or other non-academic sources. There was also evidence of transdisciplinary integration of non-experts and user-groups. Project-level results were inconclusive, leading to further analysis at working-group level.

At the working-group chapter-level, we found high levels of disciplinary specialization. All habitat-focused data chapters, plus three of the ecosystem service chapters (supporting, regulating, and provisioning) were 100% composed of natural scientists. Conversely, the cultural services chapter was 80% composed of GSSI researchers. Interestingly, some natural scientists felt the "cultural service concept was made more complicated than useful... [and was not] intuitive to non-sociologists" (R51-NS). However, despite this awareness of the cost of overcoming disciplinary barriers around cultural ecosystem services, the benefits, in terms of policy relevance and impact, may have outweighed them at the strategic project level. We did find evidence of boundary-spanning collaboration in chapters on economic and health values from ecosystems, and urban habitats. Our results suggested a contrast between evidence of interdisciplinary collaboration at the individual-level that was not matched, and perhaps obstructed, at the chapter-level.

Antecedent conditions: barriers

Case study analysis based on qualitative and observational data provided evaluative criteria on key crossdisciplinary markers: collaboration, integration, and barriers (Mâsse et al., 2008; Trochim et al., 2008). We are aware that the open-end questions respondents answered may lack the detail that could be gathered through in-depth interviews (an area of potential future research), but we believe the qualitative responses from our survey respondents suggest ways to improve disciplinary integration on national ecosystem assessment projects of this type.

Qualitative responses suggested that the UKNEA integrated policy-makers and other non-academic actors into the assessment, with actors from the policy sector included in the expert panel and contributing to authorship of the document. There was a question of how well the UKNEA incorporated conceptual and methodological approaches, and intersecting models across multiple disciplines, suggesting weakness in accounting for conceptual and methodological differences across multiple disciplines (Jacobs and Amos, 2010).

Disciplinary barriers existed in the epistemologies, methodologies, and linguistic nomenclature used by different disciplines (Bruce et al., 2004; Jacobs and Amos, 2010; Öberg, 2009). The most notable were gaps between the natural and social sciences (Becher and Trowler, 1989; Greaves and Grant, 2010). As noted by the UKNEA co-chair, the difference between the quantitative methods "of much of the economics world and the natural sciences" and the "on average more qualitative approach of the non-economic social sciences" (personal communication, Professor Watson UKNEA Co-Chair) caused challenges for the UKNEA. If researchers hope to present a holistic picture of the natural world to decision-makers, then quantitative and qualitative evidence must both be taken into account (Cooperrider, 1996; Cortner, 2000). This can challenge decision-makers who are more comfortable with quantifiable and monetizable data that fits well with their economically-oriented decision-making paradigm (Clark, 2007; Davies et al., 2000). Identifying pathways to successful quantitative and qualitative integration is a research question that might be addressed in the second phase of the UKNEA or future integrated assessment studies.

Leadership should be cognizant that the scale of national and international ecosystem assessments encourages the project to be managed through a division of labor between large numbers of geographically dispersed contributors (see similar findings in Pohl, 2008). The approach adopted in the UKNEA was to divide contributors into sections focusing on different ecosystem services, habitats, and problem areas. This risks creating disciplinary silos (Metzger and Zare, 1999), which, when combined pressure to produce "usable results" may lead to "division of labor… [between] natural or the social scientific aspects of implementation" (Pohl, 2005, p. 1175). To counteract this effect, where a project of this size is clearly delineated by chapters, the presence of interdisciplinary 'brokers' on each chapter, or spread across a number of chapters, may facilitate higher levels of project crossdisciplinary integration: "By default these [interdisciplinary] authors will also work interdisciplinary in their 'day job' more often, or regularly interact with specialists from different disciplines" (R51-NS).

Monitoring of crossdisciplinary integration was not undertaken in any formal sense on the UKNEA, but was measured informally at the leadership level. Observations of disciplinary interaction between the expert panel and chapter lead authors, and whether "the chapters more inter or multidisciplinary" were ongoing (personal communication, Professor Watson UKNEA Co-Chair). Both of these were essentially informal and personal observations. No formal mechanisms have yet, to our knowledge, been put in place for monitoring crossdisciplinary integration as the UKNEA enters its second phase. There are, however, signs of evolution in the second phase of the UKNEA. There is more emphasis on gathering clients, experts, stakeholder groups, and the coordinating authors (UKNEA, 2012). Higher level disciplinary integration is aided by the presence of all disciplines and user groups at the beginning of the process (Funtowicz and Ravetz, 1993; Gibbons, 1994).

Methodological issues

At the individual-level of analysis, it was necessary to categorize individual researchers according to their disciplinary background, in order to classify their crossdisciplinary behavior. The challenge was to classify that behavior according to its disciplinary diversity, while avoiding rigid and arbitrary boundaries (Zitt, 2005). We sought to achieve this by classifying researchers by broad disciplinary boundaries of natural and social science. There is conceptual justification for dividing disciplines between natural and social sciences (Klein, 1990). It was also a theme identified as a barrier to disciplinary integration.

At the practical level, the problem of disciplinary classification was solved in bibliometric analyses by using existing disciplinary categorization of journals (Morillo et al., 2003; Porter et al., 2007; Rafols and Meyer, 2007). Classifying the individual researcher by discipline is less clear. Academics may begin in one disciplinary field, then diversify or shift towards others. This is particularly prevalent in environmental areas, where the socio-ecological nature of problems encourages interdisciplinarity (Kinzig, 2001). Disciplinary classification is thus a blunt instrument for the types of deeper analyses that would be useful in the future. It does not, for example, answer questions about the benefits that collaboration across the natural/social science boundary provides, nor about the marginal nature of disciplinary integration (i.e., does every extra individual collaborating over the boundary of natural and social science bring similar levels of benefit to a project?).

There were also limitations in the scaling up approach applied to chapter-level analysis. Aggregation of individual behavior induced an element of double-counting in crossdisciplinary measurement. In the future, we recommend that researchers' target respondents' accounts of collaboration, communication, and interaction between chapters. This would provide data that could be contrasted independently against individual-level expertise-seeking behavior.

At the project-level, we developed measurement indicators according to the stated goals of the UKNEA to "interdisciplinary cooperation between natural and social scientists" (UK National Ecosystem Assessment, 2011, sec. 1.3). Our analysis sought to capture the disciplinary composition of the project at the chapter-level, through classification of disciplinary background of its contributors, combined with data on collaboration across the disciplines. We feel that this provides some indication of disciplinary integration across the project as a whole. However, it is limited because it does not respond to specific disciplinary objectives.

Qualitative analysis illuminated some of the gaps left by the quantitative survey method. The survey provided some useful examples of barriers to disciplinary integration. However, the challenge of integrating qualitative with quantitative data on research use and collaborative behavior, identified in our review, was not overcome (Bryman, 2007). We found that qualitative analysis was best served when providing case study 'antecedent conditions' (Stokols et al., 2008) identified in the UKNEA case of disciplinary integration. Further efforts should be made to combine qualitative data with quantitative data on composition and behavior using case study models (Trochim et al., 2008). However, cross-comparability of cases may be limited outside of team science logic model structures (Mâsse et al., 2008; Trochim et al., 2008).

An interdisciplinary UKNEA?

It is important to distinguish between appropriate levels of disciplinary integration for parts of a research project and for the project as a whole (Klein, 2008; Stokols et al., 2008; Toth and Hizsnyik, 1998). Cross-disciplinary objectives should be set by wider project goals (Stokols et al., 2008) and aspirations regarding its impact on policy (Klein, 2008). Chapter-level analysis of disciplinary integration, for example, may be better suited to those chapters that synthesize discipline-specific data human responses to natural processes and environmental change, such as chapters that measure different categories of ecosystem services (chapters 13-16), assess their contributions to society (chapters 17-20), elicit values regarding the health an economy (chapters 22-24), and provide response options for decision-makers (chapters 25-27). It is here that greater emphasis should be placed on high levels of crossdisciplinary integration. In addition, the extent to which conceptual and methodological foundations (UKNEA chapter 2) are understood and integrated in each chapter is important.

The lack of objective standards of crossdisciplinarity leaves us reliant on external recommendations of best practice disciplinary integration. Added value from disciplinary integration comes from the way it is formulated to exploring specific policy issues (Toth and Hizsnyik, 1998). Absorbing methodologies as they are used in single discipline into a kind of transdisciplinary hybrid may be desirable on a number of levels (Ramadier, 2004; Klein, 2004). However, integration can either be achieved by adding complexity or creating simplification. The process of simplification risks losing explanatory power and trust which disciplines place in their methodologies (Laniak et al., 2013). If the complexity of evidence precludes its use by decision-makers, this may contradict the standard view that increasing levels of crossdisciplinary collaboration necessarily increase the usefulness, applicability, and fit of knowledge creation to environmental problems (Laniak et al., 2013; Toth and Hizsnyik, 1998).

Economic approaches to crossdisciplinary assessments?

To better understand potential constraints on disciplinary integration, we believe that it will be important to assess crossdisciplinary environmental assessments from an economic perspective in the future. Crossdisciplinary integration will differ in its costs and benefits, depending on context. For some assessments, disciplinary integration will be more or less appropriate according to the aims of the overall project or chapters (Klein, 2008). For instance, the low degrees of disciplinary integration displayed by some chapters of the UKNEA should not necessarily be seen as a measure of failure. It may be more appropriate for some chapters to focus on collecting data from within a narrow field (Evely et al., 2010). For example, information on geomorphology or coastal processes is necessarily technical and will usually come from disciplinary 'silos'. The appropriate target for disciplinary integration in such cases is arguably low, provided there is ’synthetic disciplinarity’ at later stages of the project (Lattuca, 2001).

One must also consider the proper scope of crossdisciplinary cooperation. The costs of blanket disciplinary integration across all chapters of an assessment like the UKNEA would be high, likely with low marginal benefits accruing to at least technically-oriented chapters. If investments in crossdisciplinary research exhibit decreasing returns, where rapid gains from relatively simple forms of multidisciplinary or interdisciplinary research slow as more complete integration was attempted (recall Figure 1), it may make sense to limit attempts to attain transdisciplinarity. If there were increasing returns to scale, benefits to research integration may be modest until past a critical threshold when the benefits of investment rapidly increased (e.g., scientists started ‘talking the same language’). Given uncertainty over both the shape of the benefits curve and the potential for wide bounds of uncertainty, the appropriate level of investment in crossdisciplinarity might be highly variable even if the costs of collaboration can be adequately quantified. The proper scope of crossdisciplinary cooperation is, in principle, a research question that might be addressed either in the second phase of the UKNEA or in other research on investment in research programs for complex environmental challenges. These types of issues were explicitly raised by several participants in the UKNEA.

Conclusions

Our results suggest that the UKNEA integrated knowledge more successfully between neighboring disciplines, but struggled to overcome barriers between natural and social science. This provided a pragmatic balance for an initial exercise but that may be insufficient for longer-term policy uptake and integration of natural and social science supporting the ecosystem approach at broad scales and in complex social-ecological systems. Given the complexity of assessments such as the UKNEA, it is particularly important for project and chapter leaders to be cognizant of potential barriers to success and proactively address them in large national and international assessments. We hope that our research helps to highlight some of the key issues that need to be addressed during both planning and monitoring stages for crossdisciplinary environmental assessments in the future.

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Chapter II Strange Bedfellows: Ecosystem Services, Conservation Science, and Central Government in the United Kingdom

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Abstract

The Natural Environment White Paper represents the most important shift in conservation policy in the United Kingdom for over 20 years. It formalizes the ecosystem services approach within policy objectives and emphasizes the economic value of ecosystem services. The ecosystem services approach embodies different meanings to different groups, each suggesting distinct governance paradigms and management tools. While conservationists' support for the ecosystem services approach may stem from arguments for integrated and holistic management of natural systems, valuation efforts seek to apply economic tools to complex ecosystem processes as a means of increasing the policy salience of ecosystem services for management. Does this coupling make for strange bedfellows? We apply the Advocacy Coalition Framework to examine the alignment of the values and beliefs of key United Kingdom actors. Understanding core and peripheral values may help actors anticipate where cooperation and conflict arise, and the potential longevity of policy partnerships.

Introduction

There is widespread consensus among scientists that ecosystems are under tremendous pressure from human activities [1]. The loss of biological diversity is increasing at a rate beyond planetary boundaries [2] and is an issue in all regions and types of ecosystems [3]. An integrated approach to ecosystem-based management (EBM) increasingly became the focus of conservation scientists and environmental managers in the 1980s and 1990s [4,5]. Since the 1990s, a broader ecosystem services (ES) approach to management that also considers economic values [6] has gained traction in national (e.g., UK National Ecosystem Assessment) and international policy initiatives [7,8].

Informal interviews with conservation practitioners and agency officials in the United Kingdom (UK) suggested that their current perception of the ES approach to environmental management incorporates two distinct aspects. The first consists of a scientific systems paradigm for understanding and managing the natural world. It entails system-orientated mental constructs for environmental managers and decision-makers [9] and draws on EBM perspectives.

The second aspect is the conceptualization of natural capital stocks providing flows of valuable ES to humans (commonly economic) [6]. Ecosystem services provide a powerful analogy for the communication of environmental degradation in the dominant economic language of decision-making [10]. While the roots of the ES concept trace back at least to the 1970s [11], ES thinking has only come into the mainstream relatively recently [11,12].

The distinct emphasis of the two approaches to environmental management may appeal more or less to individuals and interest groups who hold different values. While the holistic aspect of EBM may be broadly embraced by conservationists, the quantification of ES has been criticized for "crowding out" traditional conservation interventions [13] or ignoring nature's intrinsic values not amenable to valuation [14].

In the UK, the ES approach has been adopted enthusiastically by the central government. The Natural Environment White Paper (2011) (the "White Paper") [15] was the first national-scale environmental legislation in the UK for over 20 years. It presented clear high-level policy direction that accounts for ES in local and national decision-making. It had a strong focus on the economic benefits of ES, national natural capital accounting, and the effects of ES on human health and wellbeing.

Why have UK policy-makers so readily adopted the ES approach and is this support sustainable over the long-term? Policy-makers in the UK seem, in fact, to have adopted the ES approach faster than the scientific community could provide the ecological and economic support for new policies. For example, ecologists face challenges in quantifying links between ecological structure, function, and ES of interest to policy-makers [16]. Economists are often unable to provide evidence regarding the range of ecosystem service values needed by policy-makers. The UK National Ecosystem Assessment (2011) [17], for instance, described non-monetary benefits of ecosystems to people in terms of health and shared social values rather than economic values. Current benefit transfer approaches used in lieu of primary valuation research also exhibit notoriously high transfer errors [18].

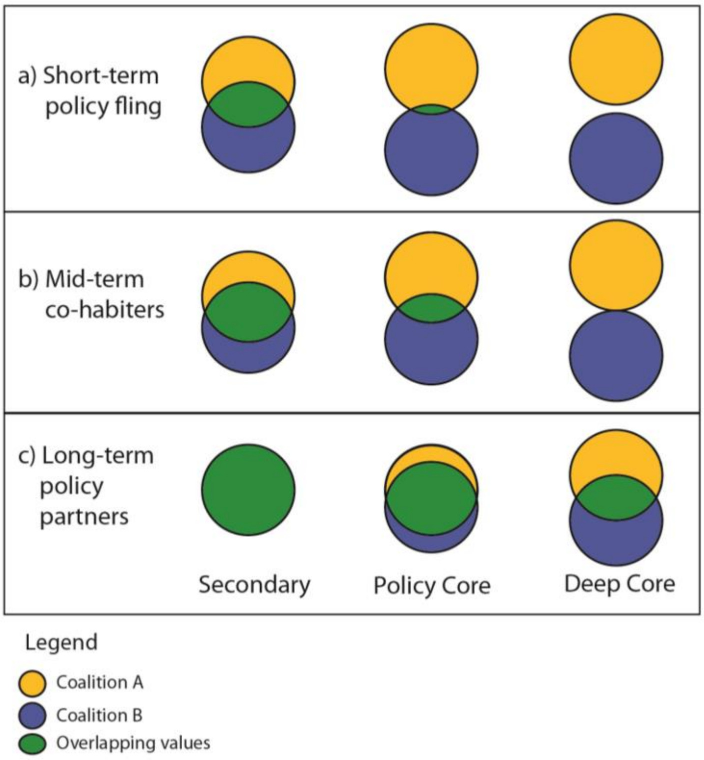
Is the dual focus on ecological systems and valuation of ES sufficient to ensure effective environmental protection? Will different actors in the policy process engage and coordinate given potentially divergent core beliefs that emphasize different aspects of the ES approach? If beliefs diverge, will weaker agreement on short-term policy and implementation issues remain? We suggest that sustainable long-term collaboration needed to successfully implement the ES approach requires an alignment of underlying motivations among policy actors. If, instead, the groups are ill-matched, they will make "strange bedfellows" [19]. We draw on the UK case to illustrate how policy actors' beliefs can be assessed and how this may help us anticipate whether the ES approach might, to stretch the strange bedfellows analogy, involve a short-term "policy fling", medium-term "issue cohabitation", or long-term "policy partnership".

Policy Coalitions

The Advocacy Coalition Framework (ACF) was developed to analyze policy implementation and change by studying how policy actors can be aggregated into advocacy coalitions bound by shared motivations and beliefs [20]. The ACF specifies three levels at which actors' beliefs are assessed: deep core; policy core; and secondary. Deep core beliefs are strongly held, relating to issues such as core political perspectives, inter-generational equity, and the existence of intrinsic environmental values [21]. Policy core beliefs are specific to particular policy issues, relating to basic normative commitments and problem causality [20]. Secondary beliefs are narrower still in scope, typically focusing on how core beliefs should be implemented in practical policies. The ACF predicts that groups who agree at the deep core level will also agree more at all lower hierarchical levels [20]. However, recent findings suggest that coalitions that differ in deep core beliefs may still converge with regards to policy core and secondary beliefs [21]. For instance, transient coalitions may unite around a shared set of short- to medium-term material interests [22].

We extend the strange bedfellows metaphor to examine varying degrees of convergence at the three levels of beliefs. In the long-term, sustainable policy partnerships overlap or converge on deep core, policy core, and implementation-oriented secondary beliefs (Figure 1). High levels of alignment increase policy partnership longevity, likely providing the predictability required for long-term, high-cost institutional innovation [23]. While it definitely pushes the analogy too far to say that sustainable policy partnerships are based on unconditional love, there are shared core values that help partners align interests over the long-term. When limited convergence exists at the deep core level, issue cohabitation may still exist at the policy core level. When coalition interests converge only slightly at the policy core level there still can be situations where short-term motivations exist for transient cross-coalition liaisons—policy flings—in which partners unite around a shared set of short-term material interests.

Figure 1 - Three classes of "strange bedfellow" coalitions that vary in their overlap in values and interests. Level of overlap between circles indicates extent to which values and interest are shared between coalitions.



Understanding the strength of motivating beliefs as the basis of collaboration between coalitions can, we believe, be used to anticipate the sustainability of the ES approach. For example, institutional innovations to protect ecological networks at the landscape and national scale are likely to require long-term, and expensive, commitment by policy partners in order to effectively address diverse stakeholder concerns, legal issues, negotiations, public communications, and policy implementation. In the UK, pilot Local

Nature Partnerships and Nature Improvement Areas are based on the assumption that durable partnerships between local government, environmental non-government organizations (ENGOs), and local stakeholders and landowners will emerge and can be informed by conservation scientists and mediated by central government agencies. These partnerships are unprecedented in the faith they put in local energy, commitments, and ownership.

As in any relationship, power issues may also come into play. Collaboration at the policy development phase may give way to the domination of one coalition at the implementation stage. It is our belief that in the ES approach this may be translated into policies that focus more on the valuation of ES, in line with central government core beliefs, than on the systems-oriented EBM orientation.

Methods

Documentation Coding

The White Paper was preceded by extensive public consultation inviting written responses from interested parties. To assess the types of advocacy coalitions active during White Paper development, we conducted a content analysis and coded 36 consultation responses with NVivo 10 (http://www.qsrinternational.com). This represented the total sample of consultation responses obtained from exhaustive online searches. Five groups who submitted comments were considered: central government; conservation scientists; landowner groups; environmental agencies, including the Department for the Environment and its "arms-length" implementation bodies, the Environment Agency, and Natural England; and ENGOs (list of consultation respondents: Table 1). We confirmed coalition labeling with analysis of each organization's stated aims, as outlined in the consultation response, or on the organization's web site. Note that the values and beliefs identified through coding of consultation responses are necessarily organizational values, drafted, approved and published by a number of individuals employed by each organization, and do not represent the personal values and beliefs of the individuals working for them. Documentary analysis provided a set of five coalitions for ACF analysis.

Table 1 - Consultation responses

Coalition[3]	Organization
Conservation science	Institute of Ecology & Environmental Management, Kew Gardens, the British Ecological Society, Institute of Environmental Management & Assessment, the Royal Town Planning Institute, Society of Biology, Geological Society, the Soil Association, the Buckinghamshire & Milton Keynes Biodiversity Society and the National Parks Authority.
ENGOs	Campaign to Protect Rural England, Green Space SE, the Kent Wildlife Trust, the Wildlife & Countryside Link, SW Landscapes, WWF, Environment Protection UK, the Green Party, Low Emissions Strategy Partnership Board, the Sustainable Development Commission, Vine, the Devon Countryside Access Forum, the Anglers Association and the Shropshire Hills AONB Partnership.
Environmental agencies	Consultation responses from Defra and Natural England. Department for Environment, Food and Rural Affairs Natural Environment White Paper: Stakeholder Workshops. 1 and 4 November 2010—Notes setting out topics to be covered.
Central government	"An Invitation to Shape Nature": consultation invitation; summary of responses; Defra web resources.
Landowners	National Farmers Union, the Yorkshire & Humber Rural Affairs Forum, the Manhood Peninsula Steering Group and the Country Land and Business Association.
Other	Research councils UK; Play England consultation; Heritage Alliance

[3] Coalitions were assigned to the organizations which authored each consultation response. Coalition labels were assigned iteratively by the lead author through analysis of their stated aims as laid out in the consultation document or on their organizational website, following Bozeman et al. (2003) Public Value Mapping (PVM). There were some examples where coalition labeling was less intuitive, such as the inclusion of the Royal Town Planning Institute in the conservation science coalition, or the Anglers Association among ENGOs. In these cases, coalition assignment was based on stated aims towards the consultation itself (ie. the Royal Town Planning Institute presented a concern for conservation aspects related to the White Paper. The Central Government coalition did not issue its own consultation responses. We analyzed the final consultation summary of results and picked out the issues that the Government response focused on, as a proxy for Central Government priorities.

Consultation documents were coded with labels reflecting themes or concepts of interest (using Nvivo 10). Our analysis involved the development and application of codes both prior to, and deriving from, the data [24]. Our initial broad coding was based on theoretical insights regarding conservation science and "central" liberal politico-economic views derived from background literature. Conservation science views were derived from literature on the human-nature dichotomy nature [25,26], wildlife conservation [27–30], the intrinsic value of nature [14,31,32], and limits to growth and sustainability discourse [33–35]. "Central" views were derived from liberal contracturalist theory [36–38], New Public Management (NPM) [39], and deliberative governance literature [40,41]. Belief components were developed from a set of six deep and policy core beliefs precepts as outlined by Sabatier [42]. These included beliefs around: the nature of man; orientation on basic value priorities; identification of groups whose welfare is of greatest concern; the overall seriousness of the problem; basic causes of the problem and; the proper distribution of authority.

Our second phase of coding derived from consultation responses. Codes were free to be adjusted iteratively during the main coding process. Consultation responses were coded by the lead researcher. The NVivo software provided outputs of total coding observations for each theme and each respondent. Coding observations were aggregated by the coalitions to which each respondent had been assigned. This provided a quantitative dataset showing the number of times each theme had been coded across all coalitions. For example, consultation presentations on issues such as "ecosystem services", "human health and wellbeing", "measurement of natural capital" etc., were collected under the coding "natural value and valuation". In this way, the broad scope of issues and concerns addressed in the source data was given shape in a way that allowed ACF analysis. We acknowledge the risk of quantification of coding based on raw observation data. This approach can lead to situations where the repetition of a particular theme or agenda by a single organization could drown out equally important, but less-repeated presentations from other organizations. We restricted code labels to one theme per paragraph of text. This was found to be an appropriate scale for written consultation responses. For aural recorded text, such as interview transcripts, we would recommend a tighter level of analysis, such as one code per question or survey section.

Table 2 - Hierarchical belief coding

	Coding observations (n)				
Deep Core[4]	**ENGO**	**Cons. Sci.**	**Agency**	**Central Govt.**	**Land-owner**
Alternatives to Neoliberal Model	61	37	-	-	-
Deliberative Democracy	-	-	21	23	71
Economic Growth Imperative	-	-	6	55	9
Environment & Society Balance	45	71	24	-	-
Environmental Fragility & Limits	59	18	-	-	-
Faith in Technocratic Solutions	58	62	8	-	-
High Value Given to Nature	41	18	-	-	-
Human Pressures on the Environment	41	21	15	-	-
NGO Mission	83	-	-	-	-
New Public Management				9	
Resource Use & Depletion	56	24	4	-	-
Statistics, Indicators & Targets	-	-	3	-	-
Understanding Ecological Processes as Requisite to their Preservation	44	23		-	-
Policy Core					
Doubts over Market Valuation	20	12	5	-	-
Doubts & Refutation of Science	-	-	-	-	25
Ecosystem Approach	213	116	39	59	-
Engaging Civil Society	-	81	7	18	9
Environmental Pressures	-	-	-	-	22
Incentives not Regulation					62
Natural Value & Valuation	64	61	29	26	-
Pressures on Growth	-	-	-	56	-
Secondary					
Command & Control	9	-	-	14	-
Economic & Market Instruments	-	41	-	3	13
Evidentiary Foundations	15	25	8	24	-
Metrics & Measurement	-	7	-	-	-
Need for Political Leadership	146	85	18	69	22
Regulatory Instruments	90	35	12	-	43

[4] The assignment of thematic codes to hierarchical levels of deep core, policy core, and secondary beliefs was achieved through researcher analysis, but grounded in the literature around conservation science and ethics, as well as neoclassical political theory.

Quantitative Coding Analysis

A coding observation was ascribed for each instance that an issue was mentioned within a paragraph. Quantitative data was subsequently divided by coalition membership to provide total numbers of coding observations for each issue per coalition.

Codes were divided into deep, policy and secondary belief levels for each coalition based on ideological closeness with pre-coding deep core issues (deep core), centrality to the substantive policy issue (policy core), and implementation practicalities (secondary) [20]. We took shared coding as an indication of belief alignment. We posited that higher numbers of shared belief issues for each coalition represented stronger coalition alignment Coalition pairing refers to coded themes that were recorded for consultation responses from organizations belonging to different coalitions. This is represented in Figure 2. Shared belief issues (y-axis) refers to the number of separate coded themes that were shared by organizations from different advocacy coalitions. Node size (circle diameter) is proportional to total coding observations shared between organizations from different coalitions, at each level of deep core, policy core, and secondary belief (represented on the x-axis). Where coalition pairings share the same number of shared beliefs, nodes may overlap, but are distinguishable by the shading, as outlined in the legend.

We represented overlapping coalition beliefs between conservation science and central government coalitions on a Venn diagram (area proportional to coding observation magnitude) at three levels of deep core, policy core, and secondary beliefs (Figure 3). Belief issues from our documentary coding table (Table 2) were labeled in the Venn diagram. Figure 4 factored shared beliefs between conservation science, central government, and the agency coalition into an area proportional Venn diagram to demonstrate overlap, and the bridging role played by the agency coalition.

Results

The number of coding observations shared by the groups submitting White Paper consultation comments is shown in Figure 2. Coalition pairing is color-coded according to the coalitions that share the same organizational beliefs. The magnitude of organizational beliefs shared between each coalition pairing is indicated on the vertical axis. Codes are divided on the horizontal axis according Advocacy Coalition Framework (ACF) belief level (recall Analysis section). The size of each circle, and degree of overlap is proportional to the number of coding observations for each coalition. The conservation science (744 comments over 132 issues) and ENGO (1076 comments over 150 issues) dyad displayed a high level of alignment of issue codes at the deep core level, while the conservation science and environment agency (199 comments over 66 issues) pairing exhibited four shared issue codes. For most dyads, however, correspondence between issue codes was low at the deep core level. Issues raised during White Paper consultations by various groups showed increased alignment at the policy core level and almost total alignment at the secondary belief level.

Figure 2 - Shared organizational beliefs between coalition pairs (size of each circle represents the number of shared beliefs for paired coalitions at each Advocacy Coalition Framework (ACF) belief level).

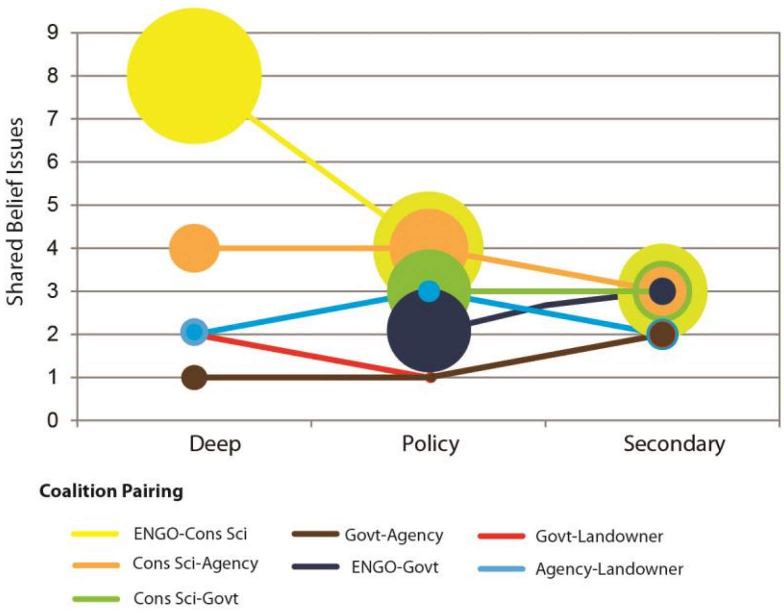
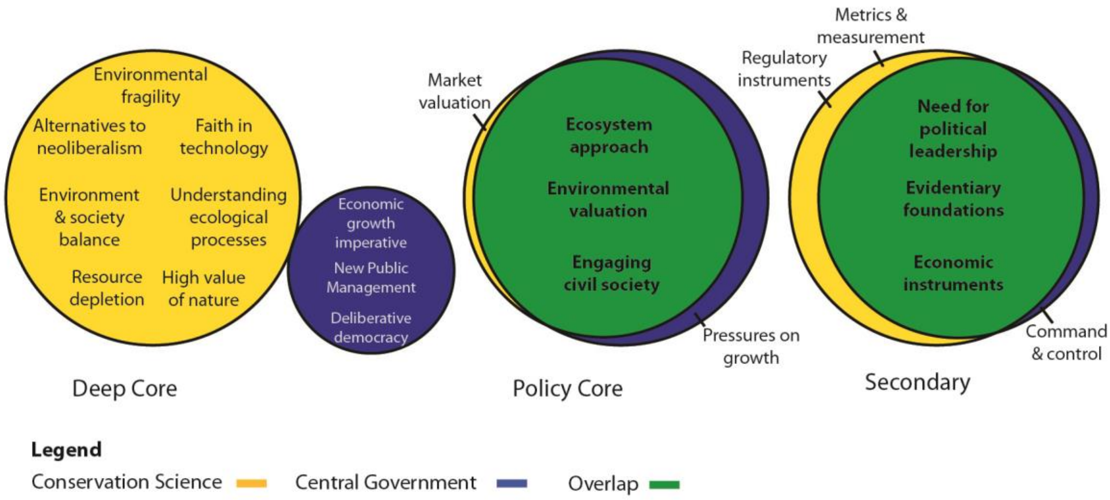


Figure 3 provides a Venn diagram of belief agreement between conservation science and central government coalitions, derived from qualitative coding (recall Analysis section). The degree of overlap is proportional to the number of coding observations for each coalition. The text inside circles indicates shared themes identified in coding of consultation responses. At the deep core level, there was complete divergence of beliefs between the conservation and central government (330 comments over 94 issues) groups (Figure 3). Deep core belief coding observations for the conservation science group related to broadly pro-environment issues like the fragility of nature, the high value of the environment to humans, and the environment-society balance, including concern for human pressures on the environment and the need for behavioral change. Concern over the dominant neoliberal worldview was also evident.

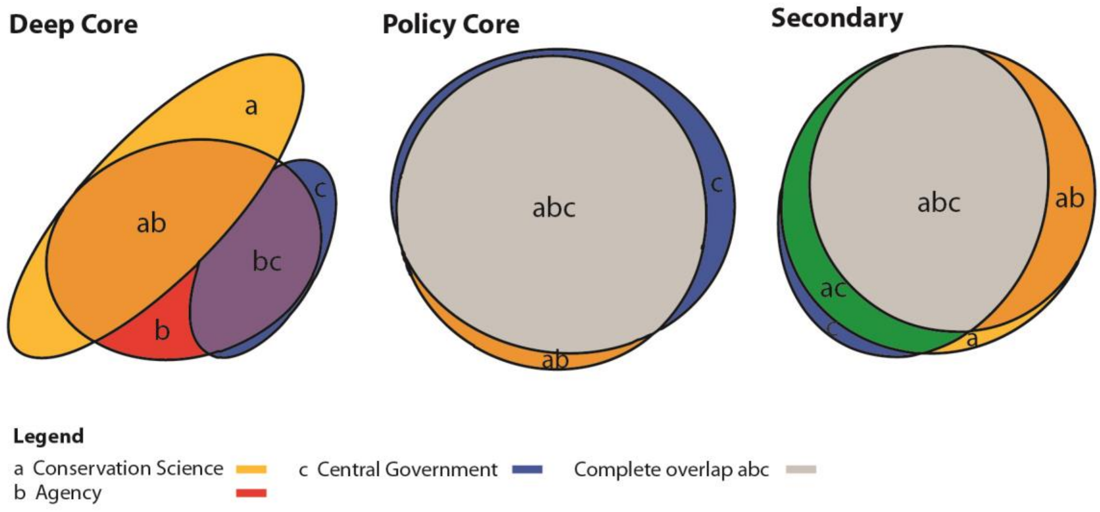
The central government group commented on deep core issues centered on governance systems and societal goals. The importance of deliberative democracy and the New Public Management paradigm, which emphasizes efficient market-led delivery of public services, were important political issues. Neoclassical or neoliberal conceptions of society and the imperative for growth were important economic issues. Policy core beliefs converged more between groups, particularly on issue-specific topics like the ES approach and civil society engagement. Still, divergence existed over issues of market approaches to environmental management. Agreement at the level of secondary belief issues was much broader.

Figure 3 - Venn diagram of belief agreement between conservation science and central government coalitions (area proportional to number of coding observations). Text inside circles indicates shared themes identified in coding of consultation responses.



The relationship between other groups was also informative. The conservation science and ENGO pairing showed greatest agreement at the deep core levels. Landowners (289 comments over 114 issues) were isolated in many of their beliefs, tending to align with the central government or agencies when they did show agreement. Figure 4 shows overlapping coding themes between conservation science, central government, and agency coalitions at different levels of deep, policy core, and secondary beliefs, derived from qualitative coding (recall Analysis section). Circle areas are proportional to the number of coding observations (recall Table 2). We found greater overlap of beliefs between the three coalitions at the secondary levels and policy core levels. Coalitions were only connected indirectly at the deep core level by the beliefs they shared with the agency coalition. The agency group (b) had higher levels of belief overlap with each of the other coalitions, suggesting that the agency group acted as an important bridge between the conservation and central government coalitions.

Figure 4 - Venn diagram of overlapping coding themes between conservation science, central government, and agency coalitions (area proportional to number of coding observations)



Discussion

There appeared to be convergence among various conservation policy actors at the policy core and secondary belief levels, including broad agreement that the ES approach was a positive progression in environmental management. The UK conservation science and central government policy coalition seems to have moved beyond a short-term policy fling; they seem to have moved in together, becoming medium-term issue cohabiters.

Convergence of beliefs at the policy core level does not itself guarantee the sustainability of long-term policy partnerships, as it may mask more fundamental disagreements in deep core beliefs. Sustainable policy partnerships can, however, be held together so long as both coalitions satisfy enough of their deep core motivations through the policy action. For conservation science and ENGOs, the White Paper advanced the protection of the natural world and was a progressive step in environmental management. For the central government, the White Paper achieved medium-term policy action objectives in the environmental sphere. The valuation of anthropocentric ecosystem service benefits also aligned well with central government deep core economic growth imperatives. The White Paper's focus on local knowledge and non-traditional governance regimes can also be made to fit with New Public Management preferences for regulatory reductions and economically efficient forms of governance [39]. Finally, at the center of the ecosystem service approach is an economic metaphor between the stock of natural capital and the flow of valuable services to humanity, an understandable idea that is politically saleable.

One could argue that there is an element of "co-opting" of economic arguments by the conservation community as it seeks to gain political traction for the overall ecosystem approach. The aim, presumably, is to appeal to policy-maker deep core values such as a faith in free market solutions. In this way, the UK conservation science community seeks to assure policy partnership sustainability by adopting positions close to government's policy core despite holding divergent deep core beliefs. Can one side appease or both sides compromise to align values further, cementing a long-term policy relationship? That remains to be seen and will depend on a variety of pressures and drivers.

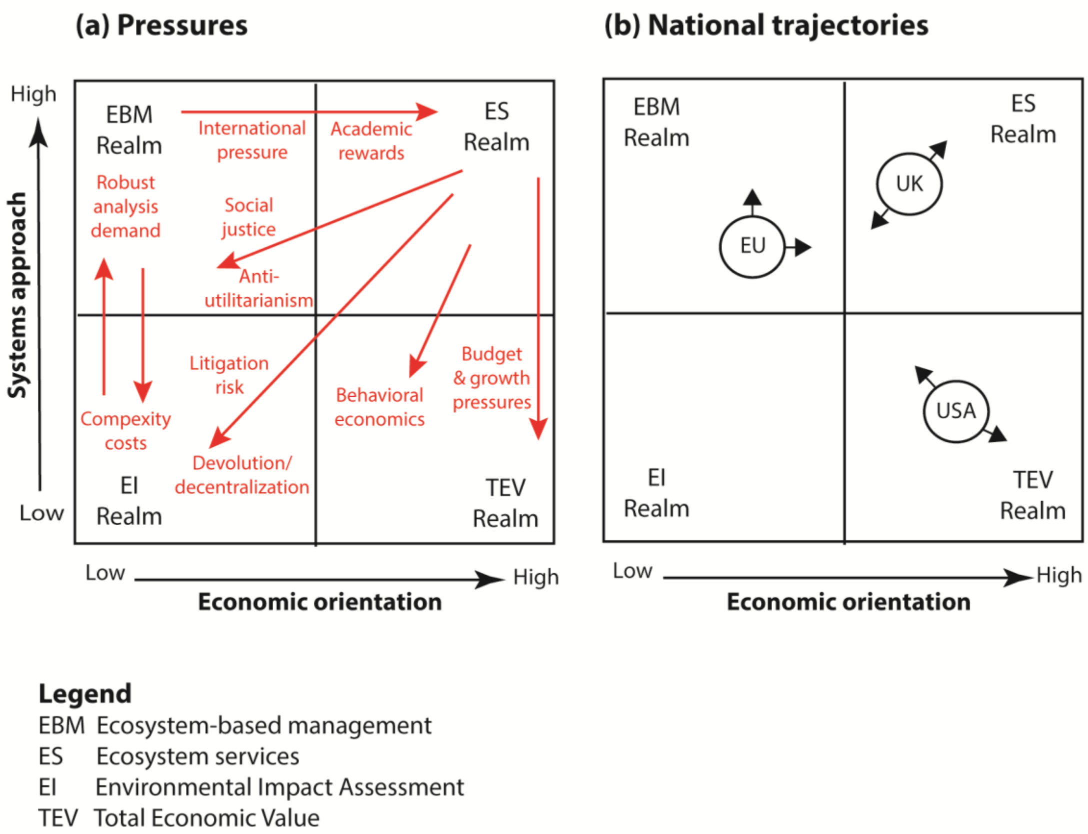
We applied a mixed-method approach to the content coding of consultation responses for the Natural Environment White Paper. This provided valuable quantitative data for analysis of shared beliefs, ads captured through the iterative coding of themes of interest. The assignment of thematic codes to hierarchical levels of deep core, policy core, and secondary beliefs was achieved through researcher analysis, but grounded in the literature around conservation science and ethics, as well as neoclassical political theory. In the future we would like to refine this method using intercoder reliability, whereby both coders were grounded in the same theoretical literature, and their coding results analyzed for cross-comparability. Finally, we acknowledge the risk of quantification of coding based on raw observation data. This approach can lead to situations where the repetition of a particular theme or agenda by a single organization could drown out equally important, but less-repeated presentations from other organizations. In subsequent applications of this quantitative coding method we have introduced measures for greater sensitivity, such as proportional coding of themes relative to total coding for that source, or binary coding, where only one observation is recorded per theme within a set measure (sentence/paragraph/section/whole text) (see e.g., Lawton and Rudd, in review - Chapter 3).

Positioning the Ecosystem Services Approach

A simple Ecosystem Services Framework

Conceptualizing the ES approach in a matrix that accounts for the scale of ecological and economic integration (Figure 5) may be useful for thinking about drivers of change. On the ecological systems axis, one can focus on context-dependent species and habitats or, at a broader level, on ecosystems and landscapes. On the valuation axis, the focus can range from narrow financial analyses to total economic value (TEV) [43] of an entire suite of ES. The two approaches are synthesized in the upper right-hand quadrant, the *ES realm*. In the upper left quadrant is the *EBM realm*. In lower left quadrant, species- and habitat-oriented assessments are more typical of environmental impact (EI) assessments. In this technical-rational *EI realm* there often are only modest levels of ecological and economic integration [44]. In the lower right quadrant, broad economic analyses are conducted for specific contexts. This *TEV realm* is where environmental economics research is typically focused. This was exemplified by the US response to the 1989 Exxon-Valdez oil spill [45], where arguments over compensation for personal damages stemming from ecological damage and restoration led to extensive litigation, new research, and controversy.

Figure 5 - Paired grids showing gradations of the ecosystem approach under (a) academic & political pressures; and (b) prospective national trajectories



Drivers of Environmental Management Approach

A variety of factors may affect where in this framework a specific regime, policy, project, or event best fit. It is useful to consider pressures that may change support for various environmental management approaches (Figure 5a). For example, in the EI realm scientific needs for more robust ecosystem-oriented analyses are potential drivers for a move to the EBM realm. However, the complexity of ecological analyses, which can be expensive and inconclusive with regards to links between ecological structure and function, may act as a counter-force.

There is now substantial international policy pressure to move from the EBM to ES realm to create economic policy relevance for growth-oriented governments. For example, the EU Natura 2000 network of protected sites, a key EBM-oriented initiative of the Habitats Directive [46], did not emphasize economic valuation but recent EU initiatives [8] are creating pressure to incorporate valuation in environmental policy [47]. Broad syntheses typical of the ES realm also tend to be highly cited (e.g., six of the 10 most influential studies in the field of environmental and ecological economics from 2000–2009 directly relate to ecosystem services [48]). Academic rewards may therefore be a driver towards the ES realm (although this is not a pressure exclusive to ES research).

Counter pressures may also be important. Issues of social and environmental justice [49] and push back against overly utilitarian approaches to environmental management [14] provide potential countervailing pressures from the ES to EBM realm. Behavioral economics [50] is also becoming increasingly influential within the economics discipline and behavioralists often question the validity and utility of ES valuation results.

Budgetary pressures may constrain integrated studies when long-term or highly transdisciplinary research is needed, effectively putting pressure towards the EI realm. The drive towards decentralization and devolution of governance can also lead to pressure to simplify ecological analyses at a local or regional level. In the UK, the effect of devolution of governance to local levels may be mitigated by Local Nature Partnerships and Nature Improvement Areas, which promote ecosystem-targeted practices like wildlife corridors, stepping-stones, and “landscape-scale’ landowner-ENGO partnership management [15]. The success of those programs, however, remains to be seen; our analysis suggested that shared policy core values diverged substantially between landowner and ENGO groups. The long-term consequences of these divergent core beliefs are difficult to predict, and are explored further in the thesis conclusion.

Another important driver of changes in environmental management orientation is litigation. While the US Endangered Species Act (ESA) legislation precludes economic concerns from explicitly influencing listing decisions, the risk of private sector litigation arising from ESA restrictions on property owners means that economic concerns may exert pressure toward the EI realm. The government may be concerned with litigation risks arising from direct financial impacts, business, or jobs, as well as opportunity costs to the private sector. Conversely, it is also possible that ENGO litigation puts the opposite pressure on governments, creating pressure to manage at higher levels of ecosystem integration [51].

Conclusions

Should national policies aspire to the ES approach, giving weight to ecosystem-oriented ecological analyses in combination with high levels of economic integration? Given the variety of ecological, economic, social, and governance factors influencing environmental management, there is no simple answer as to whether the ES approach should be more or less preferred than other management approaches. Co-habitation between regulators and conservation scientists along the UK line may be desirable but this requires understanding policy values at different levels and the possible effect of short- and long-term drivers of those values. We should expect that the slow evolution of core values in society and the quicker evolution of policy core values for various policy actors will influence the stability of existing and newly developing policy partnerships.

While ES-oriented management may be “logical’ in some countries and political contexts, it is also possible to foresee a future, especially as societies continue to push beyond planetary boundaries on multiple fronts [2], the degradation caused to the natural world demands a move away from the ES realm. This may involve, for instance, cost-effective EBM-oriented measures that at minimum cost help us achieve shared societal goals based on equity, sustainability, and well-being. We find the strange bedfellows metaphor a useful heuristic for envisioning the potential for convergence or divergence of deep core and policy core beliefs, and anticipating the possible consequences of various types of conservation policy liaisons.

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Chapter III Negotiating ecosystem concepts through the 2011 UK National Environment White Paper

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In review Research Policy

Formatting follows style of Research Policy journal

Abstract

The Natural Environment White Paper represents the most important conservation policy shift in the United Kingdom (UK) in twenty years. It formalizes the ecosystem approach within national policy objectives and emphasizes the economic value of ecosystem services. This paper explores how the influence of science on policy is mediated by context, as the UK develops an ecosystem approach to environmental policy. We aimed to understand the factors that influence the boundary-spanning of environmental science into policy decisions. Interviews with individuals involved in the development of environmental policy in the UK were designed to understand how they perceived the influence, credibility, and salience of evidence in terms of policy narratives. We found that translation and communication of ecosystem concepts to mainstream policy sectors was an important strategy to many of those involved in the development of the White Paper. Centrally-sponsored synthesis reports with entrepreneurial authors provided the most influential evidence on the process. A number of contextual factors were important in the development of the White Paper. Scientists' championing of scientific evidence for policy purposes was identified as influential in maintaining thresholds of evidence salience and legitimacy, while the strategic use of economic narratives was driven by a search for impact from the conservation science community. In the final analysis we question whether the strategy of increasing the policy salience of ecosystem service knowledge through use of economics narratives leads to losses of legitimacy among its original supporters.

Introduction

Academics and policy-makers have long worried about how to understand and improve the way science informs policy (Bijker et al., 2009; Cozzens and Woodhouse, 2002; Maasen and Weingart, 2006). Increasing the influence of scientific evidence is a particular concern for academic researchers in the conservation science sphere due to the perceived urgency of environmental problems (Dunlop, 2014; Lawton, 2007; Young et al., 2014). There are numerous ways to approach the thorny issue of 'research impact' and the interaction of science and policy in decision-making (Jasanoff and Wynne, 1998; Nutley et al., 2007; van den Hove, 2007; Weiss, 1991). Some schools of thought focus on the characteristics that make evidence relevant to decisions (Cortner, 2000; Nutley et al., 2007). Others focus on the external factors that operate to increase or decrease the influence of evidence on policy (Dunlop, 2014; Pettigrew, 2011). These non-evidentiary factors exist wherever scientific information is applied to societal decision-making, whether in media reporting (Nelkin, 1995; Wynne, 2002), political decisions (Jasanoff, 2004; Jasanoff and Wynne, 1998), or the setting and prioritization of research agendas (Bijker et al., 2009; Rudd and Lawton, 2013). In this paper we focus on how policy settings mediate the manner in which evidence is used (Dunlop, 2014). The challenge is to understand the role that non-evidentiary contextual factors play in the production, communication, and selective use of scientific evidence (Jasanoff, 2004; Jasanoff and Wynne, 1998).

Environmental science and management have undergone a shift over the past three decades, from conservation approaches focusing on protecting individual species and habitats (Franklin, 1993) to preserving and improving the integrity of ecosystems, their health, and functioning (Christensen et al., 1996; Slocombe, 1993). The result is that ecosystems approaches to conservation science and management have entered the environmental policy mainstream in recent years (see, for example, the Convention on Biodiversity COP10, 2010; Costanza et al., 1997; Defra, 2007; Millennium Ecosystem Assessment (MEA) 2005). At the same time, economic narratives of 'ecosystem services' have become increasingly prominent in environmental regulation (Cowell and Lennon, 2014; Gómez-Baggethun et al., 2010; Sarkki et al., 2013). Ecosystem services reframe the natural world in terms of the "benefits people obtain from ecosystems" (MEA 2005). They entail the quantification, and commonly monetization, of aspects of natural systems that sustain and regulate ecosystem health and functioning, or support the provision of environmental goods (Daily et al., 1997).

The economic framing of ecosystem service stocks and flows has been found to "resonate well with policymakers" (Raffaelli and White, 2013, p. 19), albeit with important differences in the way that the concepts are understood in ecological and economic terms. The UK is leading the way in the adoption of ecosystem service valuation techniques and decision-making frameworks. The Natural Environment White Paper (henceforth *White Paper,* Defra, 2011) provided policy direction towards the integration of a network of ecologically valuable sites through Nature Improvement Areas (NIAs) operating under 'landscape-scale' principles (Lawton, 2010). The White Paper also introduced concepts of ecosystem service delivery and natural stock accounting, as well as establishing the Natural Capital Committee (NCC) to advise the UK Treasury on the value and maintenance of natural assets to the economy. At a conceptual level, the White Paper aimed to "reconnect people with nature" by increasing public awareness of the importance of natural environments to health and society, and connecting economic productivity to the health of natural systems (Defra, 2011, p. 48).

Identifying the factors that account for the adoption path of an ecosystems framework in the UK at this time will be of relevance to environmental policy in other jurisdictions. Standard models of evidence impact would attribute influence to the range of evidence reports and scientific papers that provided the scientific foundation for an ecosystem service direction in the UK (for example, the Millennium Ecosystem Assessment and UK National Ecosystem Assessment; see Lawton and Rudd, 2013a). Despite the strength of this evidence base, we must recall that much of the evidence that informed the White Paper had been around for decades (see Gómez-Baggethun et al., 2010). It is therefore necessary to account for the external contextual factors that brought knowledge around ecosystem services to the forefront at the time of the White Paper (Pettigrew, 2011).

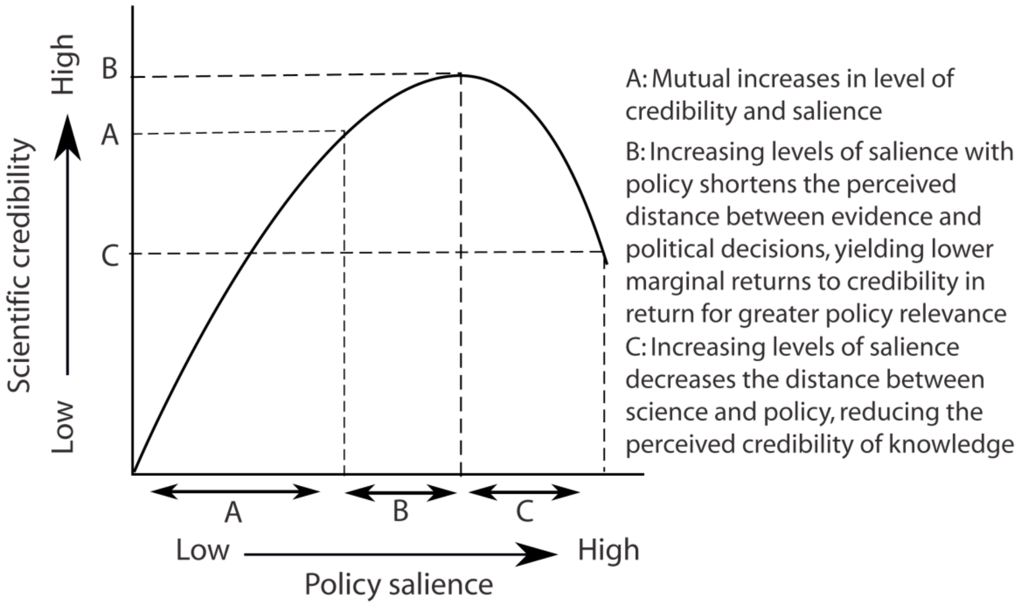
In section 2 we outline the theoretical framework for analyzing science-policy context in terms of the non-evidentiary factors taken into account in policy decisions (Pettigrew, 2011). This approach focuses on the interactions of evidence with a prescribed set of policy factors: *intermittent* variables that qualify the role of scientific knowledge on the development of an ecosystem approach in UK environmental policy. We follow Science and Technology School (STS) notions of knowledge coproduction, conceived as the social processes of negotiation and deliberation that lead to acceptance of new scientific concepts in policy decisions (Bijker et al., 2009; Cozzens and Woodhouse, 2002; Jasanoff, 2004). The negotiation of societal knowledge of the natural world is seen to operate through trade-offs between the credibility of expert-based information, its relevance to policy, and its perceived societal legitimacy (Cash et al., 2002; Sarkki et al., 2013). In section 3 we outline methods for analysing our interviews with actors' involved in the development of the White Paper. The goal of the interview was to explore perceptions of ecosystem knowledge and its strategic uptake in the policy process (Jones and McBeth, 2010; Stone, 2002). Section 4 provides an account of the range of factors affecting the utilization of evidence in the development of the UK's Natural Environment White Paper. Finally, we discuss the interactions between socially constructed attributes of credibility and policy relevance as a means of understanding how contextual factors dictate what evidence is considered legitimate to different groups, and in turn impacts on decisions (following Cash et al., 2002).

Theoretical framework

The ecological and environmental sciences make repeated calls for enhanced 'research impact' (Daily et al., 1997; Lawton, 2007; Robinson, 2006). Improving 'impact' in the traditional (linear) model is a matter of better communication, timeliness, and accessibility (e.g., Nutley et al., 2007), more integrity for science (higher legitimacy, more independence, methodological rigour) (e.g., Lubchenco, 1998; Mooers et al. 2010), or of rationalizing policy through guidelines and rules on scientific input (i.e., the evidence-based policy movement) (e.g., Young et al., 2002). The shortcomings of a purely linear model are well recognized and there is an increasing appreciation that the interactions between research and policy are complex and multi-directional, involving a range of social and cultural factors (Cowell and Lennon, 2014; Cozzens and Woodhouse, 2002; Young et al., 2014).

Evidence has a variety of attributes such as: credibility, which is influenced by intrinsic characteristics like its method, and claims to objectivity; social legitimacy, which is shaped by perceptions of fairness, appropriateness, and acceptance by multiple audiences; and its salience or relevance to decision-makers (Fischer and Forester, 1993; Cash et al., 2002). The interaction between scientific expertise and its perceived credibility or relevance is seen to operate through trade-offs that affect thresholds of societal legitimacy (Cash et al., 2002; Sarkki et al., 2013). We use Figure 1 to frame how these trade-offs might affect the legitimacy of expert-based knowledge. In the first instance, *the region of expertise* (region A), researchers value independence and distance from political processes because they can maintain scientific credibility and the societal legitimacy often associated with that independence (Brickman et al., 1985; Gieryn, 1983; Jasanoff, 1987). Although the expert maintains distance from policy-makers and can claim independence, overly critical evidence may not be useful for policy-makers (Jasanoff, 2009) or may simply not be recognized. Scientific facts alone may have low policy salience because they do not provide easily communicable narratives for the negotiation of knowledge and understanding (Jasanoff and Wynne, 1998). That is, scientific evidence can be highly credible scientifically but policy-makers may perceive it to be unimportant if, indeed, they are even aware of it. If a large imbalance exists between scientific evidence and policy relevance, this may reduce the level of relevance that experts (as well as their evidence) enjoy (Cash et al., 2002).

Figure 1 –Trade-offs between credibility, salience, and legitimacy



By aligning credible evidence to issues salient to policy-makers (and society), the gap between scientific credibility and policy may be reduced (van den Hove, 2007; Young et al., 2014). Science *entrepreneurs*, scientists who play an important role at the science-policy interface by providing information on scientific findings most relevant for policy-makers, can help shape policy-maker preferences by converting evidence into a policy-relevant form (Kingdon, 1995). When these entrepreneurs are scientific experts, they may be able apply strategic and selective tools to the evidence for bargaining or advocacy purposes (Dunlop, 2014). These 'trans-scientific expert judgements' (Brickman et al., 1985) provide input on areas of policy that go beyond their own expertise but whose scientific credibility contributes to the political construction of new knowledge. Despite diminishing returns to credibility, because individuals may be starting to advance advice outside their core area of expertise, policy salience is still increasing as existing evidence is effectively communicated to policy-makers. Many experts who translate science may be able to quickly absorb evidence from other disciplines and cut to core arguments while operating in this *region of entrepreneurship* (Figure 1, region B).

A risk arises when experts extend too far outside their own fields of expertise or when others (individuals or organizations) with lesser levels of scientific credibility use evidence to support pre-existing policy objectives. In this case, the credibility of science information may fall to a point where the perceived independence of the evidence entrepreneur is brought into doubt (Dunlop, 2014; Jasanoff, 2009). The activities of the entrepreneur may become too strongly associated with political interests (Sarkki et al., 2013). We are now in the *region of advocacy* (Figure 1, region C). Note that salience may still continue to increase (y-axis, Figure 1) because of the relevance of advocacy activities to decision-makers. Somewhere in this region, entrepreneurs transition from being advocates of excellent science (e.g., Rudd, 2014) to advocates of policy positions that filters evidence selectively (e.g., Rice and Jake, 2011).

It may be possible to track the interactions between scientific credibility and policy salience in the discursive tactics used in policy narratives. Narrative construction exists wherever individuals try to cognitively order their understanding of scientific evidence (Dryzek, 2005; Stone, 2002). Context, in this framework, includes the way that scientific information is perceived by decision-makers and society (Cash et al., 2002). These narratives can be analyzed through attention to the construction of causal stories (links constructed from a problem's cause to a wider societal effect), and policy metaphors such as comparisons between narratives founded on particular values and judgments that are subjected to interpretative discourse analysis (e.g., Jones and McBeth, 2010; Shanahan et al., 2011; Stone, 2002). This takes us a step closer to a knowledge utilization framework that accounts for the role of policy context variables at the science-policy interface.

Material and methods

Sample

We conducted semi-structured interviews with individuals who contributed to the White Paper at the policy development level. We interviewed 48 respondents, including members of: the Department for Environment, Food and Rural Affairs (Defra) and its arm's-length bodies (the Environment Agency, Natural England, English Nature and the Forestry Commission) involved in project management or scientific monitoring; ex-Ministers with environment portfolios; policy heads of national-scale environmental NGOs; landowning organizations like the Country Land and Business Association (CLA) and National Farmers Union (NFU); the Government's White Paper Ministerial Advisory Panel; and academia. We did not include individual members of the public as we anticipated their influence to be low compared to organized responses. Interviews followed the Economics and Social Research Council ethical framework. Except where agreed, anonymity was preserved by labeling organizational affiliation. Interviewees were informed that entrepreneurs would be named in our analysis.

Interview protocol

We followed a mixed structured and semi-structured interview protocol. In section 1 we asked background questions on respondents' professional role, field of expertise, education level, discipline, and role on the White Paper. Section 2 provided respondents with a list of 17 evidence documents, reports and academic literature assembled through literature review of documentary sources cited in the White Paper and its supporting documents (see Lawton and Rudd, 2013 for more detail). We asked respondents to rate the importance of each evidence source on the White Paper on a Likert-scale of 1-5 (very important to not at all important) at three temporal points: initial problem-setting; during construction of policy solutions or output documents; and, where appropriate, during implementation. We believe that these 'temporal markers' were useful for focusing interviewer attention onto changes in evidence impact over time (Schiffrin, 1988). However, we acknowledge the risk of imposing 'stages heuristic' bias on results.

Section 3 identified entrepreneurs by asking which individuals or organizations championed each evidence source from section 3. Respondents identified active individuals or organizations they associated with each evidence source. We asked a set of semi-structured follow-up questions on the characteristics that made these individuals and organizations successful entrepreneurs and the techniques they used in the policy process (Mintrom and Vergari, 1996). Section 4 provided semi-structured questions about the policy development process around the White Paper. We also asked respondents to define what they understood as the ecosystem approach and ecosystem services, and expand on how they felt the concepts were formulated in the White Paper.

Analysis

We classified evidence reports according to standard classifications for presentation purposes. Classifications included independent research institutions, ENGOs, official government publications and independent government sponsored studies. We summed and ranked median importance scores, and measured percentage change in perceived importance between temporal points.

Individuals and organizations identified as entrepreneurs were totaled and ranked across the sample, and as a percentage for each evidence source. Responses were in open non-structured format, and were coded by the lead researcher, using Internet research where necessary. Individuals from ENGOs, central Government, and the broader scientific community were combined into groups for the purposes of analysis. For clarity, we limit reporting of results to the top three evidence reports by perceived influence. Full results for all reports are provided in supporting information.

The limitation of this elicitation method is that it depends on respondents having prior knowledge of the evidence report, and of the entrepreneurs active around this report. There is also the risk of respondents repeating 'common knowledge' that certain individuals were active as entrepreneurs of the report, that represents second-hand information from other sources, rather than first-hand observations by interviewees. It may also exclude entrepreneurs associated with other evidence reports not included in the survey. However, the benefit of this method is that it focuses recollection onto a fixed set of research and policy outputs, helping to reduce the cognitive complexity of the exercise. It also reduces the number of potential entrepreneurs to a manageable level for analysis.

Interview responses were coded in NVivo (2012) using standard qualitative research protocol to code the open-end responses (Strauss, 1987). Responses were coded according to emergent themes, and total numbers of coding observations for each theme calculated. All quotes are reported with the background affiliation of the respondent. First, we questioned the data for experiences and perceptions of knowledge utilization, such as the strategies associated with higher impact evidence using techniques outlined by the Narrative Policy Framework (NPF) (Jones and McBeth, 2010; Shanahan et al., 2011). Second, we applied Interpretive Policy Analysis (IPA) methods to identify how policy actors constructed different causal stories around facts and evidence, and to explore perceptions of ecosystem knowledge and its strategic uptake in the policy process (Dryzek, 2005; Stone, 2002).

Results and discussion

Respondent attributes

We interviewed a total of 48 respondents (45 face-to-face and three internet responses). We believe that this was a satisfactory return considering that many of the individuals identified as possible interviewees worked in high-demand policy areas with high staff turnover, university positions, and private sector consultancies. Interviews were secured with four ex-Ministers for the Environment, the Defra Chief Scientific Advisor and senior civil servants. Respondents had a range of professional affiliations that included Defra (n=13); national environment agencies (n=10); ENGO (n=9); universities (n=9); central government (n=6); and landowner groups (n=4).

Perceived influence

We sought to measure the perceived influence of evidence on the development of the White Paper across a number of evidence reports. The UK National Ecosystem Assessment (UKNEA, 2011) and Making Space for Nature (Lawton, 2010, henceforth *Making Space*) had the highest importance across all three stages of problem-setting, output, and implementation (Table 1). The UKNEA was produced by a panel of independent scientists, with contributions from over 350 experts (Lawton and Rudd, 2013b). Making Space was produced independently by a panel of twelve expert academics, with two contributors each from Natural England and the landowning community. The Economics of Ecosystems and Biodiversity (TEEB) was ranked third most important. Respondents indicated that it combined independent credibility, "international expertise" (Defra), and business-insider legitimacy. Below the top three, agency and NGO-produced reports were grouped mid-table. Single study academic papers were perceived to have the lowest influence on the development of the White Paper.

There was consistency in our findings that suggested that evidence reports, and in particular large-scale syntheses of existing evidence, were influential on policy development. Making Space and UKNEA were independent reports characterized by broad and large-scale data inputs, a meta-approach to problem-framing, and production of comprehensive sets of conclusions and recommendations. Synthesis reports embodied scientific consensus, method, and comprehensiveness. Follow-up qualitative responses confirmed that "the main planks of [the White Paper] were Making Space and the UKNEA" (ENGO). These were "the source documents that everyone refer[ed] to in government circles" (Defra). Interviews confirmed that neither were novel "in the sense of new ecological ideas" (John Lawton), but synthesized "decades of work building the ability to think about the environment in a systematic way" (Natural England). This provided "credibility, direction and investment potential in the White Paper outcomes" (Environment Agency).

These results align with previous findings that showed that where decision-makers require a broad foundation for policy change, they tend to rely on "exhaustive interdisciplinary syntheses" over single reports or groups of projects (Neßhöver et al., 2013). Consolidating knowledge and communicating it in simple, uncomplicated terms and conceptual hooks facilitated understanding in the policy (and lay) communities. This was seen as an attribute that provided justification supporting "bold statements about this new approach to environmental policy" (Defra). This was seen to be very helpful for policy-makers, providing "the how and why of ecosystem science in one place" (Environment Agency). It also provided a narrative of consensus and "momentum of ecosystem-based management-thinking to government" (Environment Agency). These attributes assisted the strategic use of ecosystem narratives, placing the evidence reports into the region of entrepreneurship (recall Figure 1, region B). In contrast, single study academic papers were perceived to have low levels of influence on the White Paper. They traded off clarity for complexity, and specificity for generality, and consequently remained in the region of expertise (Sarkki et al., 2013) (recall Figure 1, region A).

Table 1 - Evidence importance and ranking across problem-setting, policy outputs construction, and implementation temporal points. Importance scores represent aggregated totals of respondents perceived importance on a scale of 0-10, where 0 is not at all important, and 10 is extremely important.

	Problem-setting		Construction of policy outputs			Implementation			
Evidence Report	Sum of median importance Scores	Rank	Sum of median importance Scores	Rank	Change (%)	Sum of median importance Scores	Rank	Change (%)	Total Change (%)
Bird Natural Thinking[i]	64	14	51	14	-20.3	46	14	-9.8	-28.1
Financing Nature[ii]	75	10	57	12	-24.0	53	11	-7.0	-29.3
Foresight Future Food & Farming[iii]	137	4	118	5	-13.9	114	4	-3.4	-16.8
Foresight International Climate Change[iv]	66	13	59	11	-10.6	52	12	-11.9	-21.2
Kremen Pollination[v]	36	16	31	15	-13.899	31	15	0.0	-13.9
Making Space For Nature[vi]	213	2	193	2	-9.4	181	2	-6.2	-15.0
Marmot[vii]	76	9	70	8	-7.9	61	9	-12.9	-19.7
NCI Valuing Our Life Support Systems[viii]	68	12	55	13	-19.1	52	12	-5.5	-23.5
Securing a healthy natural environment[ix]	133	5	122	4	-8.3	111	5	-9.0	-16.5
Silent Summer[x]	37	15	28	17	-24.3	24	16	-14.3	-35.1
State of Natural Environment[xi]	92	6	80	7	-13.0	69	7	-13.8	-25.0
TEEB[xii]	202	3	181	3	-10.4	161	3	-11.1	-20.3
ThinkBIG[xiii]	81	8	63	9	-22.2	67	8	+6.4	-17.3
UK Biodiversity Indicators[xiv]	90	7	82	6	-8.9	83	6	+1.2	-7.8

UKNEA[xv]	216	1	209	1	-3.2	192	1	-8.13	-11.1
Values of Volunteering[xvi]	35	17	31	15	-11.4	24	16	-22.6	-31.4
WWF Living Planet[xvii]	69	11	61	10	-11.6	55	10	-9.8	-20.3

[i] Bird, W., 2007. Natural Thinking: Investigating the Links Between the Natural Environment, Biodiversity and Mental Health. Royal Society for the Protection of Birds (RSPB), London, UK.

[ii] Comerford, E., Molloy, D., Morling, P., 2010. Financing Nature in an Age of Austerity. Royal Society for the Protection of Birds (RSPB), London, UK.

[iii] Foresight, 2011. The Future of Food and Farming: Challenges and Choices for Global Sustainability, Final Project Report. The Government Office for Science,London,UK.

[iv] Foresight, 2011. International Dimensions of Climate Change, Final Project Report. The Government Office for Science, London, UK.

[v] Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., LeBuhn, G,. et al.., 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecological Letters 10, 299–314. doi:10.1111/j.1461-0248.2007.01018.x

[vi] Lawton, J.H., 2010. Making Space for Nature: A Review of England's Wildlife Sites and Ecological Network. Department for Environment, Food and Rural Affairs, London,UK.

[vii] Marmot, M.G., Allen, J., Goldblatt, P., Boyce, T., McNeish, D., Grady, M., Geddes, I., 2010. Fair Society, Healthy Lives: Strategic Review of Health Inequalities in England Post-2010. Department of Health, London, UK.

[viii] NCI, 2009. Valuing Our Life Support Systems: Symposium Report. Natural Capital Initiative, Centre for Ecology and Hydrology, East Anglia, UK.

[ix] Defra, 2007. Securing a Healthy Natural Environment: An Action Plan for Embedding an Ecosystems Approach. Department for Environment, Food and Rural Affairs, London, UK.

[x] Maclean, N. (Ed.), 2010. Silent Summer: The State of Wildlife in Britain and Ireland. Cambridge University Press, Cambridge, UK.

[xi] Natural England, 2008. State of the Natural Environment Report (No. NE85). Natural England, London, UK.

[xii] TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. Earthscan, Routledge, London, UK.

[xiii] England Biodiversity Group, 2011. ThinkBIG: How and why landscape-scale conservation benefits wildlife, people and the wider economy. Natural England, London,UK.

[xiv] Defra, 2010. UK Biodiversity Indicators: Measuring Progress Towards Halting Biodiversity Loss. Department for Environment, Food and Rural Affairs, London, UK.

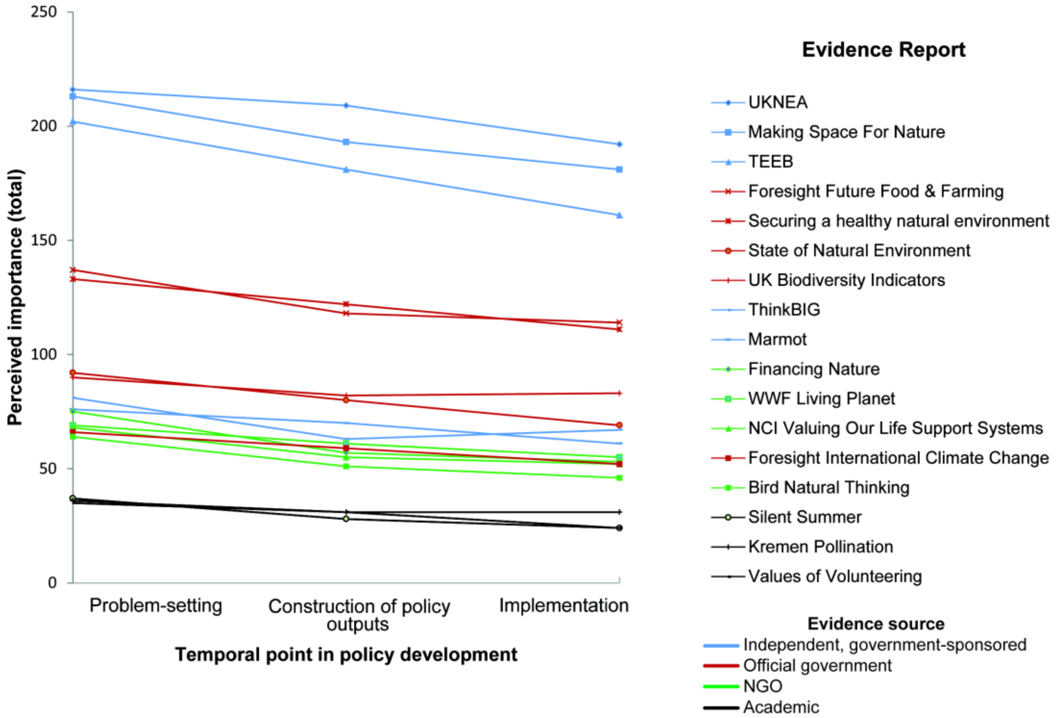
[xv] UKNEA, 2011. The UK National Ecosystem Assessment Technical Report (Technical Report: Introduction to the UK National Ecosystem Assessment), UK National Ecosystem Assessment. UNEP-WCMC, Cambridge, UK.

[xvi] Dekker, P., Halman, L., 2003. The Values of Volunteering: Cross-Cultural Perspectives. Springer, London, UK.

[xvii] Pollard, D., Almond, R., Duncan, E., Hadeed, L., McLellan, R., 2010. Living Planet Report: Biodiversity, Biocapacity and Development. World Wildlife Fund (WWF) International, Gland, Switzerland.

The timing of scientific reports exerted an influence on its uptake (Pettigrew, 2011). Previous studies have shown that what is considered to be credible, legitimate and relevant is "established an early stage of development of the process" (Tuinstra et al., 2006, p. 360). Our results suggested there was a 12% overall drop in perceived importance between the problem-setting and construction of policy outputs, a lower drop of 8% between construction of policy outputs and implementation, and a total percentage drop in perceived importance across all stages of 19% (recall Table 1). All but three cases showed a reduction in perceived importance from the problem-setting stage to text construction and implementation, suggesting that evidence influence declined over time during the development of the White Paper. The UKNEA showed an 8% drop from policy outputs to implementation, but remained the highest scoring evidence source throughout (Figure 2). The most substantial drop from problem-setting to implementation came from lower scoring NGO reports, like RSPBs Financing Nature in an Age of Austerity (2010) (-29%), and academic texts like Macleans's Silent Summer (2010) (-35%) and the Values of Volunteering (Dekker and Halman, 2003) (-31%). As attested by the ex-Secretary of State for the Environment, timing is an important contextual variable influencing policy usefulness: "early on the evidence base is absolutely key to deciding what you're going to focus on…subsequent evidence might reinforce, but it's not going to have the impact of the earlier evidence bases" (Caroline Spelman, MP). However, a trade-off also exists whereby credibility and legitimacy may suffer if rapid responses to policy issues are prioritized over methodological rigor (Sarkki et al., 2013).

Figure 2 – Declines in perceived evidence importance over temporal points, by evidence source



An important exception to this conclusion was the high importance attributed to the UKNEA. The UKNEA was published on 2nd June 2011 only shortly before the White Paper (7 June 2011). However, the influence of the UKNEA on the White Paper went further back. Interview responses indicated that individuals and whole teams across government, academia, and the third sector acted as " bridges" between Defra, the UKNEA, and the White Paper (Environment Agency). This played an important contextual role, allowing civil servants to be "quite open that they were using UKNEA to inform the White Paper" (Defra). It is important to note that quantitative measures alone failed to capture the context-specificity of the impact of this evidence report.

Entrepreneurship

The most cited names identified as entrepreneurs were Professor Bob Watson (20%), ENGOs (15%), Professor John Lawton (12%), Pavan Sukhdev (10%), the research councils (9%), and Defra (8%) (Table 2). Of the ENGO groups, the RSPB (42% of times ENGOs were mentioned) and Wildlife Trust (22%) were most commonly identified. For the Making Space report, the most identified evidence champions in rank order were Professor John Lawton, (identified by 34% of respondents), ENGOs (23%), the Environment Agency, and Defra (11%). For TEEB Pavan Sukhdev was identified as the most influential champion (72% of respondents), followed by Defra (17%), the Environment Agency and Professor

Watson (6%). For the UKNEA Professor Watson was the most commonly identified champion (39%), followed by Professor Ian Bateman, co-chair of the report (18%), Central Government and the research councils (11%).

Table 2 – Entrepreneurs by evidence report

	Making Space for Nature			TEEB			UKNEA			Total[i]	Total %	Total Rank
	n	%	Rank	*n*	%	*Rank*	*n*	%	*Rank*			
Central Government	3	6.8	5	0	0.0	5	6	10.5	4	9	7.0	9
Defra	5	11.4	4	3	16.7	2	2	3.5	6	10	7.8	7
ENGOs	10	22.7	2	0	0.0	5	5	8.8	5	19	14.7	2
Environment Agency	8	18.2	3	1	5.6	3	2	3.5	6	13	10.1	4
Landowners	0	0.0	8	0	0.0	5	1	1.8	8	2	1.6	10
Pavan Sukhdev	0	0.0	8	13	72.2	1	0	0.0	9	13	10.1	4
Professor Bob Watson	1	2.3	7	1	5.6	3	22	38.6	1	26	20.2	1
Professor Ian Bateman	0	0.0	8	0	0.0	5	10	17.5	2	10	7.8	7
Professor John Lawton	15	34.1	1	0	0.0	5	0	0.0	9	15	11.6	3
Research Councils	2	4.5	6	0	0.0	5	9	15.8	4	12	9.3	6
Total	44			18			57					

[i] Total entrepreneur observation for all evidence reports in the analysis are available in supporting information (S1)

Follow-up responses showed that Professor Bob Watson (former Chair of the MEA, Chief Scientific Advisor (CSA) to Defra, and Co-Chair of the UKNEA) was instrumental in the close collaboration between UKNEA lead authors and Defra staff. His role as CSA was "influential in pushing the UKNEA and making sure it linked up with policy" (Defra). The appointment of Professor Watson in 2007 foreshadowed the publication of the Action Plan for Embedding an Ecosystem Approach (Defra, 2007). This document aimed to "shift decision-maker opinions" (Defra) and its impact was confirmed in our data, ranking top 5 across all stages (recall Table 1). Characteristic of his championing of the UKNEA was the close collaboration between UKNEA leads and Defra staff that was both "openly discussed" (Defra) and seen as "influential in pushing the UKNEA and making sure it linked up with policy" (Defra).

Professor John Lawton was widely commended for his personal energy on Making Space. Interviewees highlighted his diplomatic approach to managing a divergent panel of academic, statutory officials, and landowners on the Making Space board. He was also notable for his communication of complex ecosystem-based management concepts into a plain-language policy-relevant form, and was credited with the creation of much of the message-framing of ecosystem concepts highlighted in the previous section. Professor Lawton was both "independent, and had enormous influence on Defra" (Environment Agency), to the extent that the Making Space report became known as the 'Lawton Review' in policy circles.

To what extent was entrepreneurship particular to the evidence report these individuals championed, or did their entrepreneurial influence extend to ecosystem knowledge at the conceptual level? As attested in our interviews, entrepreneurship was seen to operate at the scale of broader policy issues. Professor Lawton, for instance, was presented as a "figurehead" of ecosystem-based management policy solutions (Natural England). Professor Watson was seen to represent the ecosystem service agenda, while Pavan Sukhdev symbolized the approval of the business community towards ecosystem service discourse and natural capital metrics. The closeness of these individuals to both the evidence base and its policy/business applications gave them entrepreneurial influence that spread beyond the evidence report they were associated with. It extended their influence to the broader advocacy of ecosystem-based management and environmental economics within the region of entrepreneurship (recall Figure 1, region B). In turn, this shortened the distance between the evidence reports they championed, and the policy relevance of their activities at the science-policy interface.

ENGOs were the second highest ranked entrepreneur group for Making Space (22.7%). In part this was because the principles outlined in Making Space accorded with existing ENGO 'total landscape' approaches, fitting "their ethos and approaches to conservation" (National Farmers' Union). Many of these ideas had already been used as agenda-setting narratives by ENGOs under terms like 'Living Landscape', and 'Futurescapes' (RSPB 2010). There was also a sense that, while ENGOs might produce their own set of evidence reports (e.g., Financing Nature), added value could be gained by pooling entrepreneurial resources over a centrally commissioned report. In these cases, the entrepreneur (ENGOs) gained credibility through association with the evidence report. This evidence source was strategically employed for political effect, and the entrepreneur benefited by increasing their thresholds of credibility required to maintain legitimacy in the policy debate (Cash et al., 2002). However, the risk, for these groups was that their strategic utilization led to a trade-off with the perceived legitimacy of the evidence they championed. In this scenario, they were seen to enter the region of advocacy, with resultant losses of legitimacy for strategic evidence use in the eyes of other policy actors (recall Figure 1, region C).

Our findings in this section support the idea that scientific evidence does not impact on the policy process in isolation (Jasanoff and Wynne, 1998; Pettigrew, 2011; Yearley, 1988). The influence of ecosystem knowledge in the development of the White Paper was dependent on societal factors, such as its perceived legitimacy and credibility (Cash et al., 2002; Sarkki, 2013). Expert entrepreneurs were an important resource in this process, because they balanced attributes of credibility and salience in a way that other actors at the science-policy interface could not, due to their power to make 'trans-scientific expert judgments' (Brickman et al., 1985). Entrepreneurs were able to scale-up scientific evidence to broader narratives that identified problems at the level of society. The most notable success in this area was the emphasis of natural value and the disconnect individual lifestyles and economic production from the natural world, as attested by the language and concepts within the White Paper. This strategic use of knowledge and credentials made them "potentially powerful political actors" in the region of entrepreneurship (Dunlop, 2014, p. 220), while their expert status avoided trade-offs of credibility that took other groups into the region of advocacy.

Evidence perceptions and strategic narratives

We explored perceptions of ecosystem knowledge use and its strategic uptake in the policy process using narrative policy analysis techniques outlined by the NPF (Jones and McBeth, 2010; Shanahan et al., 2011). In line with previous research, we found that translation and communication of ecosystem concepts to mainstream policy sectors was an important strategy for many of those involved in the development of the ecosystem knowledge (e.g., Dunlop, 2014; Young et al., 2014). Impact strategies included conceptual 'hooks' that condensed broad and complex scientific data into simple "plain English". These comments were most commonly recorded with reference to two reports, the UKNEA (n=59) and Making Space for Nature (n=24).

The second most coded narrative strategy was message-framing, referring to strategies of evidence use, presentation, and packaging for non-scientific audiences (n=127). For instance, accessible language and narrative-framing provided decision-makers with "a story they could hook onto" (Environment Agency). Respondents indicated that ecosystem narratives like 'bigger, better, more joined-up' (Lawton, 2010) and 'ecosystem benefits to humans' (UKNEA, 2011) were strategically engaged around the White Paper. These strategies provided clarity of message for policy audiences, while the comprehensiveness of their evidence synthesis maintained thresholds of complexity and credibility (Sarkki et al., 2013).

Other evidence-based strategies enhanced the legitimacy of ecosystem narratives by associating them with established, and therefore credible, thinking in government or academia. This form of 'scaling-up' had strategic power by suggesting that ecosystem ideas were already widely accepted in these fields (Stone, 2002). Scaling-up was present in the idea that ecosystem management approaches were underway at the policy front-line, through the activities of the Environment Agency and Defra, providing impetus for government to "catch up with the direction of travel" (Defra). Finally, association with scientific consensus was very attractive to policy-makers, reducing the likelihood of negative publicity and political backlash. As one interviewee from Natural England affirmed, "looking around to see what people thought of it, policy-makers found nobody hated it. This gave policy-makers the confidence to run with it".

Two broad meta-narratives emerged from our analysis, that appeared to frame respondents' understanding of ecosystem knowledge: those based around *ecosystem-based management* (*n*=27), defined as the predominantly ecological ways in which environmental problems were framed, and those based around *environmental economics* approaches of ecosystem services, stocks, and flows (*n*=32). These broader scientific narratives had conceptual impact because they consolidated and framed the evidence in ways that had salience beyond the research community (Nutley et al., 2007; Weiss, 1991). Ecosystem-based management and environmental economics narratives assumed similar societal problems of the disconnect between knowledge of ecosystems and society's use of the natural world causes overexploitation and degradation of environmental assets (Daily et al., 1997; Helm and Hepburn, 2014; Lawton, 2010). The solution combined these narratives to produce a 'hybrid regime' that appealed to conservation science and policy audiences alike. This hybrid regime successfully combined scientific credibility and policy relevance, placing it within the region of entrepreneurship (recall Figure 1, region B).

The result was a coalition of policy narratives based on different disciplinary and epistemological foundations that served a practical purpose for policy change, leading to increases in the legitimacy and salience of both narratives of ecosystem knowledge (Cowell and Lennon, 2014). Boundary work was politically successful in this region precisely because the ecosystem approach is flexible to "negotiate the meaning of its boundaries" (Jasanoff, 2009, p. 236). This flexibility allowed it to incorporate anthropocentric outcomes (ecosystem services) and economic metaphors (stocks and flows) into knowledge discourse, framing arguments in economic narratives with which they are already familiar (Daily et al., 1997; Farley, 2012).

The combining of these two strands of ecosystem knowledge into a hybrid regime was seen to be motivated for strategic purposes by different groups. The use of environmental economics narratives was understood as a strategic gain by some, "deliberately framing [the environment] in economics language in order to make a case to people not coming from an ecological perspective" (Natural England). Metrics used to quantify the natural world for decision-making were understood to allow central government to "buy into [ecosystem service] thinking" because it had "a very economic framework" (ENGO). The key task was to present environmental issues "in a way that convinced Treasury and Central Government" (Caroline Spelman, MP). These sentiments were shared by many in the conservation community, where "increasingly sophisticated message-framing" (Natural England) aimed for "more traction and better fit for policy implementation" (ENGO). This created incentives for scientists to adapt their messages to suit policy actors better (Sarkki et al., 2013).

For others, such as those in government and regulatory agencies, the combining of ecosystem-based management and environmental economics responded to a policy demand for ecosystem knowledge framed in economic narratives (Sarkki et al., 2013). This resulted from "recognition that in order to affect the ecosystem approach properly there needs to be some monetary valuation of the benefits of ecosystem services" (Natural England). By placing a "supply value on the management of the natural world" (Environment Agency), and matching that up to the exchange value of economic activities in the wider economy. Environmental economics narratives were well-received because they accorded with neoclassical models of natural management and decision-making (Farley, 2012; Gómez-Baggethun et al., 2010). As a result, those in decision-making positions could move environmental considerations from "things which have long been regarded as externalities" (Barry Gardiner, MP), to "build them into decision-making" (Hilary Benn, MP).

Predictions for the future

The inconsistencies between economic and ecological framings of natural systems have been explored in detail by previous authors (e.g., Gómez-Baggethun et al., 2010; Limburg et al., 2002). By identifying strategic uses of evidence-based narratives in the coproduction process, it may be possible to anticipate the evolution of ecosystem knowledge in the UK policy context. Interview responses highlighted some concerns with environmental economics narratives. One ENGO employee criticized the coupling of "the very detailed side of ecosystems…and the more straightforward expression of ecosystem services beneficial to people and the economy". There was a sense that distinctions between the systems approaches and economic valuation had to be maintained, since the two bodies of knowledge had very different epistemological understandings of the complexity of the natural world. There were concerns about the "commodification" of the natural world (Environment Agency). Finally, there were concerns about the types of institutional and regulatory arrangements that would arise, with the risk that environmental economics approaches may lead to a predominance of decisions based on easily quantified economic flows, "rather than ecosystem health and function" (ENGO).

Looking forward, we can apply our understanding of trade-offs between credibility and salience to anticipate possible future directions in policy and the success of the ecosystem hybrid regime (recall Figure 1). As economics framings are used increasingly to appeal to policy audiences, the gap between ecology and economics becomes more problematic (Dunlop, 2014; Farley, 2012). A concurrent risk of alienation may grow among the scientific or conservation community, as they begin to fear that ecosystems messages have been captured by economic logics of marginal value, compensating variation and substitutability (see Cowell and Lennon, 2014). Trade-offs between the strategic use of environmental economics narratives and the dominance of ecosystem service policy instruments for mainstream advocacy purposes would lead to losses of legitimacy among its original supporters (recall Figure 1, region C), putting a serious strain on the sustainability of the hybrid regime of ecosystem-based management and environmental economics (Lawton and Rudd, 2013b).

A cursory view shows that the regulatory arrangements set up by the White Paper have been largely divided along ecosystem-based management and environmental economics lines. Nature Improvement Areas apply management regimes that enhance ecosystem connectivity, resilience, and health. The Natural Capital Committee, in contrast, is characterized by environmental economics language of Pareto improvement, aggregate stocks, and end-point services, using tools like offsetting and assumptions of substitutability with other forms of capital (Defra, 2013). However, there are signs that a sustainable hybrid regime could emerge. Although in its early stages, the Natural Capital Committee has been notable in its sensitivity to ecological thresholds, non-marginal step-changes, and non-substitutable components of the system (Helm and Hepburn, 2014). There is also discourse, if not action, around the use of ecosystem services in the early Nature Improvement Areas pilots (Defra and Natural England, 2013). The direction of future environmental policy in the UK will depend in part on how evidence-based narratives of ecosystem-based management and environmental economics interact with other policy context factors in the negotiation of ecosystem knowledge, and the resultant sustainability of the hybrid regime.

Conclusion

We identified a number of non-evidentiary factors to account for the adoption of ecosystems frameworks in the UK in the Natural Environment White Paper (2011). We analyzed the process by which ecosystem knowledge was utilized in the policy process through trade-offs of expert credibility and policy salience (Cash et al., 2002; Sarkki et al., 2013). First, centrally-sponsored synthesis reports with entrepreneurial authors provided the most influential strategic narratives that helped balance expert information with salient communication. The interaction operated in a region of entrepreneurship, which balanced thresholds of expertise with boundary-spanning activities that made scientific information relevant to broader policy issues (Cash et al., 2002). Second, senior scientists' championing of evidence for policy purposes was identified as influential in maintaining thresholds of evidence credibility and salience. The timing of scientific reports exerted an influence on its uptake (Pettigrew, 2011). Nearly all evidence reports experienced a drop in perceived influence from a peak in the problem-setting stage, through text construction, to implementation. Henceforth, the influence of evidence was found in strategic narratives constructed around scientific information by groups within the policy negotiation process (Jasanoff, 1987; Weiss, 1991).

Third, narrative policy analysis helped to identify the strategic use of policy metaphors that draw comparison between one narrative and another, implying prescription and judgments about the correct interpretation of knowledge (following Jones and McBeth, 2010; Shanahan et al., 2011; Stone, 2002). This strategy was found to play out particularly strongly for economic narratives of ecosystem value. Narrative analysis also highlighted how policy actors scaled-up issues by associating them to problems of greater perceived societal weight. We found evidence of causal stories linking the cause of a problem (continued biodiversity loss) to its solutions (ecosystem-based management or environmental economics approaches) in ways that bestow credibility and authority on groups offering certain solutions.

Finally, the salience of ecosystem narratives was found to be most powerful when they combined ecological and economic concepts. Respondents attested to the fact that environmental economics narratives fulfilled an impact objective for the ecological science community. Elsewhere it has been argued that strategies of ecosystem knowledge use stem from a strategic desire for impact, but that to date they have been largely conceptual (Dunlop, 2014). We found evidence that ecosystem knowledge, and environmental economics narratives in particular, was used strategically to increase the salience of environmental evidence for policy. On the one hand, the conservation science community sought to mainstream the argument that natural systems were being undervalued in decision-making through association with neoclassical market-based narratives. On the other, environmental economics narratives balanced expert credibility with the salient economic language of governance. This attested to the strategic power of economic narratives of the natural world (Cowell and Lennon, 2014; Gómez-Baggethun et al., 2010; Sarkki et al., 2013). The question, going forward, is the extent to which economic framings may 'crowd out' ecosystem-based management narratives of connectivity, function, and health (Gómez-Baggethun et al., 2010; Limburg et al., 2002). This has important implications for how policy-makers use evidence and should shape the research community's impact objectives. Over time, it may be possible to qualify contextual variables across multiple case studies, with a view to building a set of broader regularities of contextual factors within science policy interfaces. This paper takes us a step closer to lifting the veil on the role of policy context variables at the science-policy interface.

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Chapter IV. A narrative policy approach to environmental conservation

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Abstract

Due to the urgency and seriousness of the loss of biological diversity, scientists from across a range of disciplines are urged to increase the salience and use of their research by policy-makers. Increased policy nuance is needed to address the science-policy gap and overcome divergent views of separate research and policy worlds, a view still relatively common among conservation scientists. Research impact considerations should recognize that policy uptake is dependent on contextual variables operating in the policy sphere. We provide a novel adaptation of existing policy approaches to evidence impact that accounts for non-evidentiary 'societal' influences on decision-making. We highlight recent analytical tools from political science that account for the use of evidence by policy-makers. Using the United Kingdom's recent embrace of the ecosystem approach to environmental management, we advocate analyzing evidence research impact through a narrative lens that accounts for the credibility, legitimacy, and relevance of science for policy.

Introduction

Ecological and environmental sciences are strongly motivated by narratives of the need to take urgent measures to halt environmental damage and conserve at-risk species, habitats, and ecosystems (Alcamo et al. 2005). The scale of potential problems such as biological diversity loss (Barnosky et al. 2011; Rudd 2011a) and catastrophic climate change (Weitzman 2011) puts an obligation on scientists to engage in research that helps address the "most urgent needs of society" (Lubchenco 1998, 494). The message from within the science community is that scientists must approach research with clarity and direction, and consider its eventual impact on society (Owens 2005; Lawton 2007; Jenkins et al. 2012). Despite calls for scientific engagement in societal decisions, environmental scientists, like those in social science fields, often express dissatisfaction at their level of impact in the policy sphere (Robinson 2006).

The converse narrative is that policy-makers are saturated by information from multiple sources; traditional civil service advisory services, academic researchers, think tanks, and social media all contribute to the deluge. Policy-makers juggle advice from social science, natural science, economic analyses, public opinion polls, as well as pressure from interest groups and other departments. In this context, policy-maker time, attention, and energy are scarce resources that must be manipulated to affect policy change (Zahariadis 1999).

Emerging directions in research impact assessment seek to account for the non-evidentiary factors that influence evidence use in the policy process (Contandriopoulos et al. 2010). The uptake of scientific evidence by policy-makers, for instance, is heavily dependent on contextual variables like the receptivity of decision-makers, timing and problem relevance, and competing societal values that may not be readily shifted by the communication of evidence (Sarewitz 2004; Lawton 2007). Contextual factors can create "non-receptive settings for new ideas" or "more receptive contexts for more developed recognition" (Pettigrew 2011, 351). Of course, one could argue that this is a very old approach, going back to John Dewey (e.g., Bromley 2006). The challenge is to "decode the context and understand its impact on knowledge use" (Contandriopoulos et al. 2010, 468).

It is commonly assumed that greater connectivity, integration, and crossdisciplinary inclusion increase the likelihood of evidence, knowledge and concepts transferring from conservation science to influence decisions (Wittrock 1991; Gibbons 1994; Frederiksen et al. 2003). It follows that there is an obligation on researchers to increase the impact of conservation science (i.e., that decisions that lead to continued degradation of the environment are caused by incomplete or imperfectly communicated information, and that better provision of factual information leads to better decisions - Owens 2005; Lawton 2007; Daily et al. 2009). A narrow approach to the science-policy process fails to address non-evidentiary barriers in the form of the pre-existing beliefs, vested interests and public attitudes that may be as important as the research produced (Contandriopoulos et al. 2010).

As environmental problems are increasingly identified as socio-ecological in nature (Folke et al. 2007; Liu et al. 2007; Reid et al. 2010), consideration of public policy influences on evidence impact will become more important. We believe that conservation scientists can benefit from concise descriptive tools that map contextual factors that affect the use of their evidence in decision-making. For instance: what strategies do evidence-users adopt in their policy arguments (Radaelli et al. 2013); why can the same body of evidence be used in justification of divergent political positions (e.g., the recent badger-culling debate in the UK; see Woolhouse and Wood 2013); and what role do underlying motivations play in the advocacy of evidence-based narratives (Jones and McBeth 2010; Shanahan et al. 2011)?

We outline one policy approach, the Narrative Policy Framework (NPF) (Jones and McBeth 2010; Shanahan et al. 2011), that accords with recent awareness of the importance of ‘stories’ in science communication (Leslie et al. 2013). We outline a novel adaptation of the NPF for the assessment of non-evidentiary ‘societal’ influences on decision-making. A narrative framework of the effects of evidence on policy provides a foundation for fuller, context-dependent understanding of the knowledge mobilization process.

Background

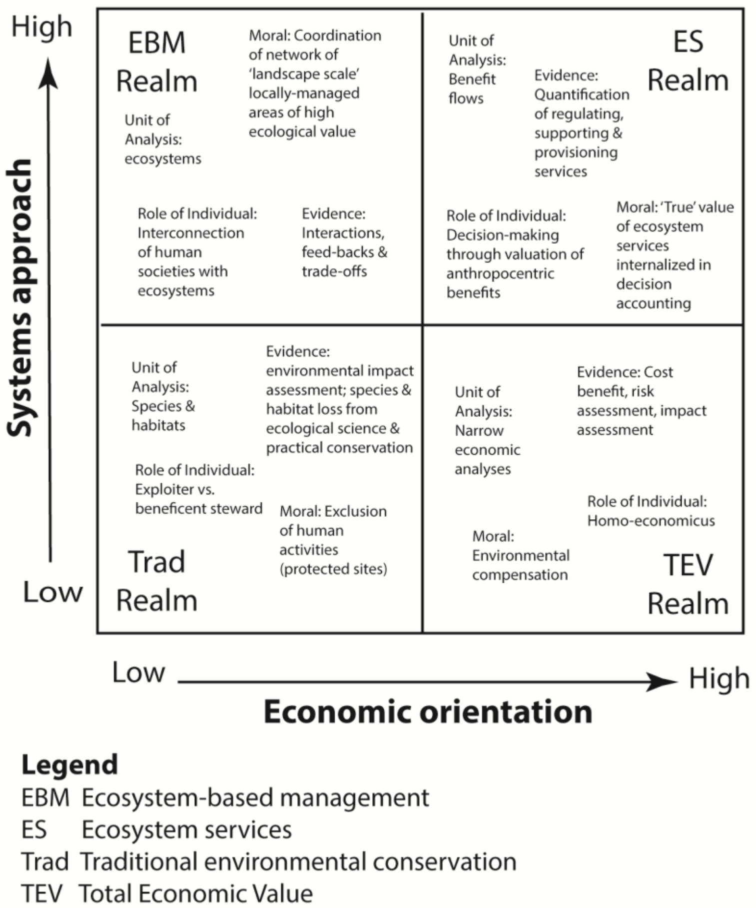
We draw on the example of ‘ecosystem-based management’ (EBM) in the UK (Lawton and Rudd 2013) to illustrate the development of an approach to evidence impact assessment with the NPF. EBM narratives were central to the Natural Environment White Paper. The White Paper (2011) provided a strategic government response to continued biological diversity loss, habitat fragmentation, and declining ecosystem quality in the UK (Lawton 2010). It took an ‘integrated approach’ aiming for a ‘resilient ecological network’ of well-functioning ecosystems and sustained economic growth within an ecosystem service paradigm.

The UK example could point towards two alternative policy responses: an EBM narrative that seeks to preserve the natural world by increasing coherence, resilience and integrity of natural systems (e.g., Grumbine 1994); and an ‘ecosystem services’ (ES) narrative that emphasizes the delivery of anthropogenic benefits flowing from the services natural capital assets that support them (Daily et al. 2009), perhaps at the exclusion of those elements that do not contribute directly to human well-being, such as some aspects of biological diversity (Cardinale et al. 2012).

EBM is premised on the narrative that traditional scientific approaches to species and habitat protection have failed to arrest biological diversity loss (Lawton 2010). Conventional management has omitted the interactions of species as components in an interconnected ecosystem, and of coupled human societies and natural systems. The EBM narrative therefore focuses on evidence of ecosystem interconnections, functioning, and ecology (Lister 1998).

ES narratives aim to identify, catalogue, and quantify the services on which natural and human systems rely so that they may be brought into societal decision-making processes. Evidence production focuses on quantifying the stocks and flows of benefits that ecosystems provide (Daily et al. 2009). ES narratives provide a powerful discursive tool in the communication of environmental degradation, driven by a desire for greater policy uptake of evidence leading to better decisions for the preservation of ecosystem features (Lawton and Rudd 2013). Figure 1 outlines differing underlying assumptions about unit of analysis, role of the individual, evidence-base and narrative morals between EBM, ES, traditional conservation and cost-benefit total economic valuation (TEV) realms (adapted from Lawton and Rudd 2013).

Figure 1 – Competing environmental management counter-narratives



Research utilization

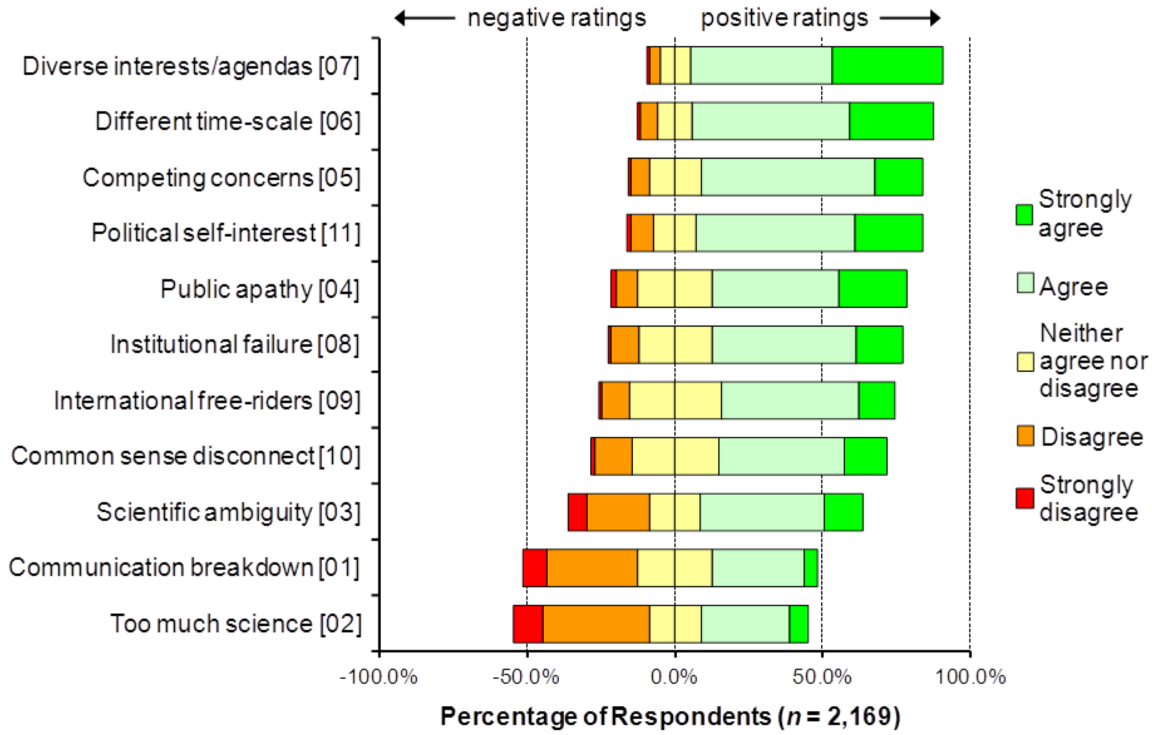
There are three main schools of thought within research utilization. One takes a traditional linear approach, where the influence of a piece of evidence can be directly quantified in economic or bibliographic terms (Griliches 1998). A second emphasizes diffuse impact, the gradual saturation of ideas of concept through the 'agora' of the research community (Weiss 1979). The third focuses on networks or brokerage models that emphasize the personal bridging connections that individuals create between research and policy institutions (Oldham and McLean 1997).

Implicit in many of these accounts of research uptake are assumptions about the divergent nature of the research and policy worlds. Two important narrative streams within the research utilization literature were identified by Wittrock (1991). 'Divergers' emphasize the need to 'bridge' the gap between science and policymaking. They see the relational logics of science and politics as 'incompatible' and either/or' (Hoppe 2009, 237). Divergers typically follow linear narratives of instrumental impact, focused on the directly measurable impacts of a single evidence source. This position may be conceptualized as dichotomous, or zero sum, with evidence either having a direct and immediate influence on decision-making or having no impact at all (Beyer 1997). Many scientists that adhere to this logic may be advocates of ‘aligned research’ (Rudd 2011b) if research impacts are viewed from a narrow perspective.

‘Convergers’ observe no policy gap. They believe science and politics ought to be “natural allies in preparing collective decisions” (Hoppe 2009, 235). In line with ‘Mode-Two’ perspectives on research impacts (Gibbons 1994), convergers emphasize the fluid boundaries between research and policy communities, envisaging policy-makers involved from the earliest stages of research design and experts occupying decision-making positions (Frederiksen et al. 2003). The expert themselves may act as a stakeholder or their research output may be used independently by any number of divergent interests within the pluralist policy process.

We posit that the diverger viewpoint still prevails in the conservation science community. Academic conferences ring with calls for policy to listen more to the scientific community, as if the role of the researcher is one of passive information supplier. Concurrently, ‘policy-making’ is portrayed as a black-box, many-times removed from the world of research. For example, in a series of surveys of international environmental scientists (Fleishman et al. 2011; Rudd 2011a; Rudd and Lawton 2013 plus four M.Sc. student theses at University of York), we asked scientists’ level of agreement with 11 possible reasons proposed by Lawton (2007) for a lack of science uptake in environmental policy formulation and implementation. Among the 2169 scientists who completed surveys, we found high levels of agreement that the policy world operates on different time scales, with different interests, and with a disconnect from science (Figure 2). We would welcome similar research on policy-makers attitudes to the same set of science-policy issues.

Figure 2 – Level of agreement among scientists (n=2,169) with a series of 11 possible reasons for a lack of science uptake in environmental policy formulation and implementation[1]



In practice, decisions are made in a plural setting involving multiple autonomous and quasi-autonomous NGOs, think-tanks, and politically-engaged scientists (Sabatier and Jenkins-Smith 1993). While some academic writers show an awareness of the "messy, complex and iterative process" of evidence-based decision-making (Lawton 2007, 465), still

[1] The reasons include: 01 Scientists are to blame: we are simply not getting the message across clearly enough; 02 There is too much science out there and politicians do not know where to go for the best or most relevant information; 03 The science is ambiguous and there are no clear answers; politicians use the uncertainty to avoid difficult decisions; 04 There is insufficient public support for what 'ought' to be done, or politicians believe that there is insufficient electoral support for necessary actions that may threaten voters' cherished lifestyles; 05 Policy has to be formulated to take into account many other legitimate issues and constraints, not least the cost of various options; 06 Scientists and policy-makers work to very different time-scales; 07 Politicians are caught between the policy options that emerge from the science, and other powerful interest groups with different agendas; 08 There is 'institutional failure': we have the wrong decision making bodies, poor (or no) 'joined-up' government and contradictory policies in different parts of government; 09 Policy solutions require bilateral or multilateral international agreements which are susceptible to free-riding and other types of cheating; 10 The scientific advice flies in the face of received political wisdom, dogma, or other deeply entrenched beliefs; and 11 Some politicians are corrupt and out to look after personal interests. Questions drawn from Lawton (2007).

too many err towards policy 'gaps' and research 'supply and demand'. Assessing the impact of a single evidence source ignores the additive effects provided by factors not traditionally considered, such as differential resources of time, attention, and network connections (Frederiksen et al. 2003). It also ignores the additive effect of multiple evidence sources acting together.

The challenge of taking a converger approach to the assessment of the effects of research on policy is that societal (political) decisions are multi-criteria in nature, characterized by diverse attributes, complex information, and fluid boundaries between actors (Sabatier and Jenkins-Smith 1993). Impact cannot be attributed to the citations received by a single paper, or the economic returns from an individual invention or concept, since wider impact may be heavily context dependent upon the "receptive contexts" around a body of research (Pettigrew 2011, 351).

Narrative Policy Framework

In this paper we highlight calls for a fourth approach to assessing the effect of research on policy (Contandriopoulos et al. 2010). We illustrate how existing tools from political science can be applied to assessments of research uptake to develop an analytical framework that accounts for non-evidentiary factors.

Work to date has focused on the effect of contextual factors in evidence utilization in the field of health policy. Both case study comparisons and focus groups have been used (e.g., Dobrow et al. 2006). Tummers et al. (2012) analyzed how different contextual factors influenced willingness to implement health policy. They focused on the 'what' of policy content, the 'where' of organizational context, and the 'who' of personality characteristics of the professionals involved in implementation, and found that contextual variables had a significant effect on policy implementation (Tummers et al. 2012). Our approach assesses the 'how' of policy development, captured in the strategic use of evidence through policy narrative analysis.

The Narrative Policy Framework (NPF) accounts for policy change by tracking the use of 'strategic narratives' (Jones and McBeth 2010). Information is presented as stories in the policy process (Leslie et al. 2013). Dominant narratives are not only shifted by empirical evidence but also as a result of counter-narratives ability to "tell a better story" (Roe 1994, 40). Narrative studies provide coding guidance for analysis of policy subsystems (Jones and McBeth 2010; Shanahan et al. 2011). Narratives, stories, and plots are used by actors to structure causal explanations through construction of arguments, dramatic rhetorical devices, characters, and morals (Stone 2001). Standard narrative features can be organized around a set of evidence-specific themes of scientific credibility, societal legitimacy, and policy salience (relevance) (Cash et al. 2002). This provides multiple channels of influence for analysis. This can help make sense of the evidence-policy interface and identify how combinations of strategic narratives may affect policy change.

The influence of evidence-based narratives on policy is also dictated by their credibility, perceived legitimacy and fairness (Cash et al. 2002). It follows that in multi-actor systems, narratives are accepted by groups depending on the extent to which they accord with their shared beliefs and policy motivations (Sabatier and Jenkins-Smith 1993; Shanahan et al. 2011). This is less likely in conflicting and adversarial policy areas, such as climate change, where debate is driven by values and identity politics (Jasanoff and Wynne 1998). Finally, the relevance of evidence-based narratives depends on their relevance to decision-making bodies (Cash et al. 2002). Timeliness with the political agenda, appropriate technologies, and narrow research focus all influence the likelihood that evidence-based narratives enjoy policy traction (Lawton 2007).

Narrative setting

In the NPF, the narrative setting is commonly the 'policy arena' as perceived by actors within it. Typically this is the substantive or geographical area addressed by the policy (Jones and McBeth 2010). This provides the bounds for discursive analysis and qualitative coding (see below).

For example, in a preliminary analysis of the UK 'Natural Environment White Paper' (hereafter 'White Paper') a delineated sample frame (authors of the White Paper, contributors to surrounding documents, and public consultees) provided the starting point for review of a body of evidence that influenced policy development (Lawton and Rudd 2013). This provided insights on evidence used in narratives around EBM and ES, as well as broader issues (e.g., level of government intervention and deficit reduction) salient to policy-makers. It found that difference in evidence-based narratives indicated a difference in underlying motivations between the research and policy communities in their support for EBM and ES outcomes (recall Figure 1).

Current approaches to the evaluation of research on policy already encourage researchers to think ahead towards the extended societal impacts they expect of their work (Owens 2013). All too often this question asks researchers to stare into the unknown. Foresight and scoping of future potentialities requires structure: prior experience and trends shape our expectations and bound the limits of the possible. New challenges, however, constantly arise (Weitzman 2011) and scientists need to creatively use their networks and knowledge to develop new solutions to emerging challenges (Latour 2013). Preliminary scoping of the policy setting to which evidence is destined still, however, serves an important purpose in framing expectations of research impact. It provides important feedback on policy gaps and evidence opportunities, and may help reshape research objectives. This should not be seen as an optional extra, but as an important step in crafting conservation science that meets the needs of society (Lubchenco 1998).

Characters

Actors are partly self-defined by their roles and partly characterized by others within policy narrative discourse (Stone 2001). Humans portray themselves and each other as archetypes: common characters include ‘heroes’, portrayed as fixers of the problem, ‘villains’ who cause the problem, or ‘victims’ (Jones and McBeth 2010). Empirical analysis of characterization narratives provides an indication of the degree of legitimacy policy narratives hold in the eyes of advocacy coalitions.

In the White Paper setting (2011), heroes differed between groups. Heroes within the academic community included well-connected scientific experts with a record of influencing policy. Conservationist heroes included ENGOs who advocated environmental protection while for centrist policy-makers heroes were pragmatic ‘fixers’ who provided workable and salient solutions. Villains were characterized for blocking progress or the objectives of a particular group. Villains for those with conservation aims for the White Paper included politicians or interest groups with pro-development objectives, while for centrist or landowner groups villains sought to restrict economic growth through conservation interventions. Victims may include those groups suffering as a result of the problem, such as marginalized groups opposed to the commodification of ecosystem services (or indeed non-humans).

We also propose that an additional set of characters are needed specifically for understanding the processes by which evidence influences policy decisions. Entrepreneurs are seen as crucial in many models of policy change (Kingdon 1995). Entrepreneurs act as champions of an idea, evidence report, or policy issue. They apply their personal energy, network connections, and reputational resources in bringing an environmental issue to policy-maker attention (Zahariadis 1999). In the UK, for instance, entrepreneurship gathered around key evidence sources such as the UK National Ecosystem Assessment (2011) and the Lawton Review (Lawton 2010). ‘Charismatic experts’ (Robert Watson, previous chair of the Millennium Ecosystem Assessment, and John Lawton, both eminent ecologists with a track record of policy success) enhanced the credibility and legitimacy of those reports and, by extension those strategically citing them for policy purposes. The wider expert author base associated with the research behind these reports was also a powerful surrogate for credibility. Concurrently, evidence documents gained extra salience through the industry, political resources, and personal connections provided by the evidence entrepreneur.

We believe that evidence-policy archetypes in the White Paper case are applicable other evidence-policy settings. The development and testing of science-policy 'ideal types' drawn from empirical narrative analysis would contribute added nuance to the traditional divergent model of 'researchers' and black-box 'policy-makers' (Hoppe 2009).

Dramatic rhetorical resources

Dramatic narrative strategies are "used by policy actors to expand their power and ultimately win in the policy process" (Jones and McBeth 2010, 345). Evidence-based narratives may be 'captured' by groups and institutions (Radaelli et al. 2013). Ecological narratives of heightened values from interconnected ecosystems, for instance, were mobilized by conservation groups as justification for 'landscape scale' interventions (Lawton 2010). Once co-opted for political use, empirical content may be embedded within the broader body of evidence through 'keystone documents' that synthesize and give narrative coherence to assembled facts and evidence.

Broader lessons can be drawn from the interactions of rhetoric, timing and windows of opportunity with scientific evidence. The scientist rhetorician only became a thing of the past in the last century (Ashley-Smith 2000). At the point of engagement with other sectors of society - whether explained to a friend or formally presented to elected officials – scientific evidence becomes part of a story told to convince, enlighten or persuade (Roe 1994). The problems faced by conservation scientists are increasingly understood to be interlinked and socio-ecological (Folke et al. 2007; Reid et al. 2010). Understanding rhetorical archetypes underlying societal decision-making is one component of this shift in knowledge production.

Policy solutions (moral of the story)

Narrative morals provide the argumentative logic behind policy actor mobilization of evidence (Jones and McBeth 2010; Shanahan et al. 2011). The moral of the story in a policy narrative is often portrayed to prompt action and as a policy solution (Stone 2001).

Narrative strategies may be employed to increase the apparent concordance of counter-narrative morals to the core beliefs of another coalition. For instance, the 'coupling' of ES narratives of economic evidence to EBM narratives of ecosystem value may be seen as a strategy for increasing the relevance of the EBM counter-narrative to government and decision-makers (Lawton & Rudd 2013). In this case, narratives of monetary quantification provide legitimacy for environmental conservation claims within centrist decision-making institutions, where economic narratives hold epistemic authority. Conversely, economic narratives may reduce the legitimacy of coupled EBM-ES solutions, because the objective of 'capturing' policy audiences may raise doubts about the credibility of evidence-based narratives.

Robust, testable, repeatable evidence gathering and analysis is the core ontological motivation behind conservation science. However, it is clear that evidence is also used to frame messages behind sweeping narratives that encompass facts, values, interests, and aspirations (Jones and McBeth 2010; Shanahan et al. 2011). Convergent conservation science should operate with an appreciation that information is communicated through simple and memorable stories (Leslie et al. 2013). A divergent approach to science-policy impact makes no attempt to shape these morals (Wittrock 1991). A converger approaches them from a position of deeper knowledge than many other societal actors (Hoppe 2009).

Conclusion

The conservation of biological diversity is increasingly seen within an interconnected socio-ecological sphere (Folke et al. 2007). Evidence about complex ecological systems must be approached in combination with knowledge of human societies (Liu et al. 2007; Reid et al. 2010). Context-dependent understanding of the knowledge mobilization process provides a reflexive approach that accounts for non-scientific factors (Latour 2013). Implementation of the UK White Paper, for example, is likely dependent upon contextual factors like resource availability (financial, organizational, labor), resistance from coalitions with different policy objectives and priorities, and the unanticipated effects of concurrent policy measures being enacted in other sectors.

Existing approaches to understanding the knowledge mobilization process share a common core assumption that evidence content is the 'central' input that impacts on research uptake, and that contextual factors are 'peripheral' barriers to impact. Underlying this approach is a presumption in favor of evidence as the primary driver of societal decisions. We suggest that the reality, as seen from the 'other side' of the science-policy gap, is that evidence is one of a set of equally important inputs into societal decisions. Greater understanding of this alternative perspective on the evidence-policy process can be explored in detail through an analysis of the discourse and narratives of actors involved in the decision-making process (Jones and McBeth 2010; Shanahan et al. 2011).

A converger approach to research impact assessment, on the other hand, places evidence within a broader set of considerations in a pluralist society (Hoppe 2009). Instead of the often intractable goal of aligning policy with research, this approach seeks a more comprehensive understanding of the variables at play in the decision-making process. It suggests that scientists are thoroughly enmeshed in the value adjudication processes needed to establish best practices (Rudd 2011b) where the conservation of biological diversity can be positively influenced (Jenkins et al. 2012). The goal is an empirical understanding of the actual, not imagined, place social and natural science evidence plays in each value-laden decision-making context.

We have tried to provide context throughout this paper with reference to the UK Natural Environment White Paper. We have a detailed USA case now in final preparation that explored natural resource managers' research priorities in light of their attitudes to bridging science-policy interactions on a converger/diverger spectrum (recall Hoppe 2009). Respondents were grouped using latent class analysis based on these responses and tested for significance with sociodemographic and professional affiliation (e.g. scientists versus policy-makers). The outcome (Table 1) developed twelve questions that can be used to test for converger/diverger orientation going forward (this amended converger/diverger list has already been applied to scientists' perspectives on ocean research, see Rudd, in review; and science-policy workers' attitudes to natural resource management, see Lawton, Rudd, and Fleischman, in review).

Table 1 – Amended converger/diverger statement list

No.	Statement	Conv/ Div.
1	Worthwhile policy ideas emerge from science, but scientists have no responsibility for disseminating the policy implications of their research among policy-advising bureaucrats and politicians.	D
2	No matter their differences, science and politics eventually serve a similar function creating conditions for cooperation between people.	C
3	It is admirable that scientists translate political ideas into transparent models, and objectify them into measurable indicators.	C
4	The client or principal defines what knowledge is relevant	C
5	It is only natural for bureaucrats to collaborate with scientists; after all, research is a link in the chain of policy implementation.	C
6	There will always be a political struggle about values; and correspondingly, types of knowledge that align with, or deviate from political value systems	C
7	In public policy, learning is limited to instrumental, financial and organizational matters.	D
8	Dealing with uncertainty primarily is a matter of thorough and honest political debate.	C
9	Most of the time it is concepts, models or story lines originating in science that are the glue in agreement on policy development issues.	C
10	It is in the nature of things that politics and science are incompatible activities	D
11	When the chips are down, lay and practitioners' knowledge have less value than scientific knowledge; therefore, they deserve no standing at the policy table:	D
12	Scientific experts and advisers are lawyers: their business is advocacy for political positions	D

Context is important and an NPF approach to account for it through preliminary analyses of policy settings, awareness of narrative archetypes, strategic narratives and rhetorical devices, and a willingness to engage in the currency of compelling stories and morals may help conservation scientists tell their story more effectively (Jones and McBeth 2010; Shanahan et al. 2011). Better decisions over the management and conservation of the natural world can only occur through better targeted, credible, and salient evidence (Cash et al. 2002). The creation of policy narratives and compelling morals is a vital task for conservation scientists (Leslie et al. 2013). In the case of EBM, for instance, failure to engage on the part of the conservation science community may lead to the predominance of morals around the marketization of nature, with limited considerations for habitat connectivity and systems understanding (Lawton and Rudd 2013). We hope this will aid in achieving both routine research impact assessments and greater ambitions for conservation science influence on policy-making processes.

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Chapter V. Science, policy, and resource management discourses in the United States

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Abstract

Recent studies elicited the top priorities for research to inform natural resource management in the United States. Conducting this research and applying it to practice will require collaboration among scientists, practitioners, and policy-makers. Whether these efforts succeed will depend to some extent on differences in each group's personal and professional attitudes about the nature of interactions among science, policy, and practice. We conducted a survey of scientists and policy-makers in the United States to test whether individuals involved in natural resource management could be classified on the basis of personal values (defined on the basis of Schwartz's theory of universal values) or professional attitudes. We classified respondents' attitudes about the interface between science and policy as either converger (high compatibility between science and policy) or diverger (low compatibility between science and policy). We used latent-class cluster analysis to identify patterns of agreement or disagreement with statements about the science-policy interface. The majority of respondents gave high importance to the preservation of the natural world, with an interesting split between those who sought impact and influence. Eighty-three percent of the 126 survey respondents exhibited attitudes characteristic of convergers. We also found a small group of strong convergers within our sample. Respondents under 50 years of age were significantly more likely to exhibit converger attitudes than respondents over 50, suggesting that converger attitudes may be gaining cultural acceptance as generations shift. The distinction between convergers and divergers contributes to understanding of variation among policy actors' views about the science-policy interface. Differences in professional attitudes span a spectrum rather than form a dichotomy, and relative to personal values, may be more useful for developing more-robust methods for testing attitudes about science-policy interactions.

Introduction

During the last two decades social science has provided new insights that may contribute to bridging boundaries between conservation science and policy [1–4]. As in other disciplines [5–8], the use of credible evidence increasingly is being emphasized in making decisions about natural resources [9]. Scientists and policy-makers sometimes have reappraised their responsibilities [10] and sought additional training to support their new roles. Scientists have often increased their efforts to disseminate and present their research in formats designed to increase uptake by policy-makers and other research users [11,12]. A common current perspective among environmental scientists and funders of those scientists' research is that crossdisciplinary cooperation and engagement is crucial for solving complex environmental challenges [13–15]. There has been a shift in some quarters toward collaborative, crossdisciplinary approaches to sustainability science [16–18] and aspirations to transdisciplinary transcendence of existing disciplinary boundaries [19–22]. The shift in emphasis has highlighted differences in perspectives about evidence-policy interactions [23–25].

Fleishman et al. [26] generated priority research questions applicable to natural-resource management in the United States through an inclusive process of interviews with senior decision-makers; a broad solicitation of research needs, framed as questions, from scientists and policy-makers; and a workshop where scientifically oriented individuals responsible for managing and developing policy related to natural resources narrowed the research needs to 40 questions. A subsequent survey of scientists and policy-makers was used to rank the 40 research questions [27]. The ranking revealed significant differences in research priorities among respondents, but the differences were unrelated to a range of typical demographic and professional covariates.

Two possible reasons for the latter results were of particular interest to us. First, the difference in orientation may be related to professional values. In his examination of foundational work on research utilization theory from the 1970s and 1980s, Wittrock [28] found no consensus among producers and users of scientific research about the modes through which science translated into policy. Building on Wittrock's work, Hoppe [8] hypothesized that differences in attitudes toward the science-policy interface among researchers and policy-makers could be classified according to a two-by-two matrix of prioritization of science or policy evidence and convergent or divergent logics. Divergers emphasize the gap between science and policy and the primacy of either sphere. They typically assume that science and policy are largely incompatible and they hold relatively linear views of applications of research, focusing on the direct, measurable effects of a single evidence source on policy decisions [28]. Convergers, by contrast, are more comfortable with blurred boundaries between science and policy. They regard science and policy as united in practice by a common goal of improving society, and may not perceive a science-policy gap [8]. Convergers believe that science and politics should be aligned and that members of both sectors should collaborate to make decisions. They tend to be preoccupied with societally relevant problems, their research generally is interdisciplinary or transdisciplinary, and they have a propensity to engage both users and producers of information throughout their research [28].

Second, personal values may affect research orientation. Universal human values have been grouped on two scales [29–31]. The endpoints of the first scale are self-enhancing values (e.g., materialism, personal ambition) and self-transcending values (e.g., benevolence, respect for the environment). The endpoints of the second scale are traditional values (e.g., duty, family loyalty, social order) and openness to change [29–31]. Personal values influence how individuals interpret novel information and connect to issues of wider societal interest [32,33]. Value measures therefore may provide insights on otherwise inexplicable prioritization choices [27].

Our research tested two main hypotheses: that there were no differences in professional attitudes toward the science-policy interface among USA scientists and policy-makers in our sample, and that there were no differences in underlying personal values among respondents. Differences in professional attitudes or personal values, either alone or in combination, may help explain differences in research priorities and provide a basis for identification and implementation of actions to increase cooperation among scientists, managers, and policy-makers with diverse views about natural resource use and management.

Material and methods

Rudd and Fleishman [27] surveyed 602 resource managers, policy-makers and their advisers, and scientists in the United States. We distributed a follow-up survey to the 335 respondents who provided contact information and were receptive to further contact.

We developed a three-part, Internet-based survey to examine whether professional attitudes toward science and policy could be classified as converger or diverger, and whether personal values were related to research orientation (Supporting Information 1). The survey followed the Economics and Social Research Council’s framework for research ethics [34] and was approved by the research ethics board of the University of York’s Environment Department. After an introduction to the survey and information about data confidentiality, we collected demographic and professional information. We used x^2 tests to examine whether demographic and professional characteristics of our sample and that of Rudd and Fleishman [27] differed significantly.

We asked respondents which of a set of 15 personal value statements (Table 1) guided their lives and, for value statements to which they were not opposed, the extent to which each functioned as a guiding principle on a scale from 1 (not at all important) to 7 (supremely important) [31]. We then asked respondents to indicate the extent to which they agreed or disagreed with nine statements that could be used to differentiate convergers from divergers. The nine statements were those that Hoppe [8] found to be significant in factor analyses that distinguished among perspectives about science-policy boundaries (Table 2). Before implementing our survey, we used the literature to classify each statement as typical of converger or diverger values [28]. Subsequently, for any of the nine statements with which respondents strongly agreed, we asked the respondents to elaborate why they strongly agreed.

Table 1 – Personal value statements (following Stern et al. 1998) presented to respondents and abbreviated references to these values in the text.

Value type[i]	Abbreviation
Biospheric	
1. Protecting the environment, preserving nature	Preserving nature
2. Unity with nature, fitting into nature	Unity with nature
3. Respecting Earth, harmony with other species	Respecting Earth
Altruistic	
4. World at peace, free of war and conflict	Peace
5. Social justice, correcting justice, care for the weak	Justice
6. Equality, equal opportunity	Equality
Conservation or traditional	
7. Honoring parents and elders, showing respect	Respect
8. Family security, safety for loved ones	Family security
9. Self-discipline, self-restraint, resistance to temptation	Self-discipline
Self-enhancement or egoistic	
10. Authority, right to lead or command	Authority
11. Influential, having an impact on people and events	Influence and impact
12. Wealth, material possession, money	Wealth
Openness to change	
13. Varied life filled with challenge, novelty, and change	Variety
14. An exciting life, stimulating experiences	Stimulating experiences
15. Curious, interested in everything, exploring	Curiosity

[i] Value statements retained in the latent class analysis are in boldface.

Table 2 – Statements about the science-policy interface that were presented to respondents and used to differentiate convergers from divergers

Statement[i]	Shortened statement
1. Worthwhile policy ideas emerge from science, but scientists have no responsibility for disseminating the policy implications of their research to policy.	Responsibility for disseminating the policy implications of research
2. No matter their differences, science and politics eventually serve a similar function creating conditions for cooperation between people.	Science and politics serve a similar function for cooperation
3. It is admirable that scientists translate vague political ideas into transparent models, and objectify them into measurable indicators.	Translation of vague political ideas
4. In my field, one scientific discipline dominates; when researchers or advisers from other disciplines come up with different recommendations, most of the time they hit a brick wall.	One scientific discipline dominates
5. It is only natural for bureaucrats to collaborate with scientists; after all, research is a link in the chain of policy implementation.	Collaboration with scientists
6. Uncertainty reduction through science or expertise is hardly possible; learning is a matter of trial-and-error in practice.	Uncertainty reduction through science
7. In public policy, learning is limited to instrumental, financial and organizational matters.	Policy learning is limited
8. Dealing with uncertainty primarily is a matter of thorough and honest political debate.	Uncertainty reduction through political debate
9. Most of the time it is concepts, models or storylines originating in science that are the glue in agreement on policy development issues.	Story lines originating in science

[i] Value statements retained in the latent class analysis are in boldface.

We used latent-class cluster analysis to identify distinct patterns of respondents' agreement or disagreement with the 15 value statements and nine science-policy interface statements (i.e., patterns that would suggest the respondents were convergers or divergers) [35,36]. We used the difference in Akaike's Information Criterion (AIC) between models to identify the latent-class model most strongly supported by the data [37]. We compared the results of model selection with reference to our research question. We considered models with ΔAIC<3 to have equivalent support [38]. To test whether indicator variables were locally independent, we used the bivariate residual Pearson χ^2 statistic. We sequentially deleted statements from the latent-class cluster analysis until no bivariate residual coefficients were significant at the 5% level (S3). We analyzed only those surveys for which data were complete; we excluded surveys that included *not applicable* responses.

We used Kruskal-Wallis tests to assess whether median ratings of statements differed among latent classes. When Kruskal-Wallis tests were significant, we used Tukey-Kramer post-hoc comparisons to identify which pairs of median rating were significantly different. We set the threshold of significance at alpha <0.05. We used Friedman test to assess whether differences in median ratings differed across all statements.

We used Bonferroni-adjusted χ^2 tests (implemented with Chi-Squared Automatic Interaction Detector (SI-CHAID) [39]) to systematically examine whether members of clusters differed with respect to demographic and professional covariates (professional sector, age, gender, education level, disciplinary training, and years of professional experience). We used Friedman tests assess whether research prioritization perspectives from the prior survey significantly differed across professional attitude or personal value clusters [27].

We asked the respondents to elaborate the reasons for supporting professional attitudes or personal value statements with which they strongly agreed. The lead interviewer used standard qualitative research protocol to code the open-end responses [40]. Responses were coded according to emergent themes, or key phrases, on the basis of respondents' interpretation of the statements with respect to the science-policy interface.

Results

Survey responses

Of the 335 scientists and policy-makers we contacted, 180 accessed the survey. Of those 180, 153 completed the survey (46% of the sample). After eliminating surveys from respondents who did not provide a response for one or more statements, we were left with 126 surveys for the final analysis (38% of the sample). Respondents included 50 academics, 34 science-oriented individuals employed by governmental organizations, 19 policy-oriented individuals employed by governmental organizations, 11 individuals employed by nongovernmental organizations, 4 individuals employed by the private sector, and 8 individuals employed by other organizations.

The sector affiliations of respondents in this survey were not significantly different from those of respondents in Rudd and Fleishman [27] (x^2[5 d.f., *n*=728]=2.16, *p*=0.83). Full demographic information is in S2. We found significant differences in education level between our sample and that of Rudd and Fleishman [27]. A smaller proportion of respondents in our sample had Bachelor's degrees and a larger proportion had postgraduate degrees (x^2[3 d.f., *n*=728]=11.18, *p*=0.01). The proportion of respondents with disciplinary training in agricultural and biological sciences was significantly greater in this sample than in that of Rudd and Fleishman [27] (x^2[1 d.f., *n*=330]=6.9, *p*=0.001).

Latent classes

Personal values

We first ran latent-class models that included a maximum of eight clusters. The probability of belonging to Latent Class x is defined using the posterior membership probability (for full discussion, see 35). The three-cluster model had lowest AIC (S3). On the basis of AIC values, we retained a three-class latent-class cluster model. Nine of fifteen personal value statements sequentially were deleted from the latent-class cluster analysis to eliminate all significant bivariate residual coefficients that were significantly correlated (Model 10, S3). The value statements that defined the clusters spanned four of the five categories: biospheric (*preserving nature, unity with nature*), altruistic (justice), self-enhancement (*authority, influence & impact*), and openness to change (*variety*) (recall Table 1). We then ran latent-class models that included a maximum of five clusters. The four-cluster model had the lowest AIC. However, the level of support for the three- four- and five-cluster models were almost equivalent (∆AIC=2.3). We elected to retain the three-class model (Model 10 S3) for further analysis; the difference in entropy R^2 was negligible (0.01) and the three-cluster model had fewer parameters.

The null hypothesis that median ranks were equal for all statements was rejected (*S*=621.5, 14 d.f., *p*<0.001). The null hypothesis that median ranks for each statement were equal across the three clusters was rejected at the 1% level for all significant statements in the final latent class model (Table 3). Unless stated below, Tukey post-hoc tests rejected the hypothesis that median ranks of statements in the final latent class model were equal between pairs of clusters at the 5% level. Clusters 2 and 3 did not statistically differ in their ranking of statements 1 (*preserving nature*, *p*=0.98), statement 2 (*unity with nature*, *p*=0.50), and statement 5 (*justice*, *p*=0.94). This indicated considerable convergence of personal values between clusters 2 and 3 around biospheric and altruistic positions. Clusters 1 and 2 did not statistically differ in their ranking of statement 10 (*having authority, p*=0.06), while clusters 1 and 3 did not statistically differ in their ranking of statement 13 (*variety*, *p*=0.98).

Table 3 – Difference in mean rating of personal value statements

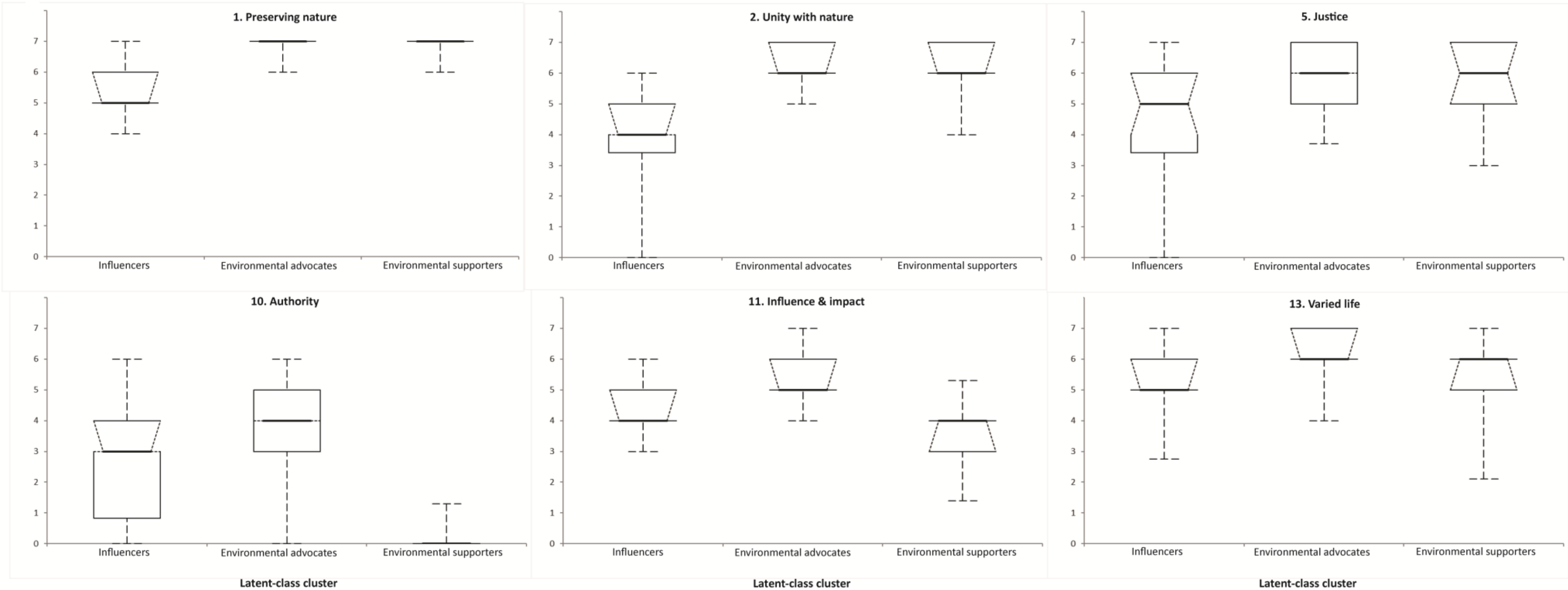
	Difference in mean rating across clusters[i]	Difference in mean rating between clusters (0-7 scale) [ii]		
Statement	Krusal-Wallis H	Cluster 1-2	Clusters 1-3	Clusters 2-3
1. Preserving nature	69.49*	-1.4*	-1.4*	0.0
	(0.000)	(0.000)	(0.000)	(0.982)
2. Unity with nature	65.78*	-2.4*	-2.1*	0.3
	(0.000)	(0.000)	(0.000)	(0.503)
5. Justice	14.88*	-1.3*	-1.1*	0.1*
	(0.000)	(0.000)	(0.006)	(0.943)
10. Authority	46.50*	-0.8	2.8*	3.6*
	(0.000)	(0.059)	(0.000)	(0.000)
11. Influence and impact	33.55*	-0.9*	0.8*	1.7*
	(0.000)	(0.000)	(0.007)	(0.000)
13. Variety	21.67*	-1.0*	-0.1	1.0*
	(0.000)	(0.000)	(0.983)	(0.000)

[i] Statistical significance in Kruskal-Wallis test in parenthesis. Rankings that were significantly different at the 1% level in Krusal-Wallis tests are denoted with *

[ii] Statistical significance in Tukey-Kramer post-hoc comparisons in parenthesis. Rankings that were significantly different at the 1% level in Tukey-Kramer post-hoc comparisons are denoted with *

We labelled cluster 1 (41% of respondents) as *influencers*. Members of this cluster consistently attached lower importance to biospheric and altruistic statements. It attached lower importance to the self-enhancement value of *authority*, but more importance to influence and impact and openness to change (Figure 1). We labelled cluster 2 as *environmental advocates* (37% of respondents). Members of this cluster consistently attached higher importance to biospheric and altruistic values. Respondents in this cluster attached moderate importance to *authority*, but higher importance to *influence and impact*, as well as openness to change. We labelled cluster 3 as *environmental supporters* (22% of respondents). Respondents in this cluster attached the same level of importance to biospheric and altruistic values as *environmental advocates*, but differed significantly in the very low importance respondents in this cluster attached to authority, and the moderate level of importance they attached to influence and impact. No professional or demographic covariate differed significantly among clusters.

Figure 1 – Level of agreement with 15 personal value statements by each of three latent class clusters on a scale from 1 (not at all important) to 7 (supremely important). 0, opposed to the value statement. Boxes include the first through third quartiles. Line, median ranking; capped bars, 5th and 95th percentiles. Full statements are in Table 1.

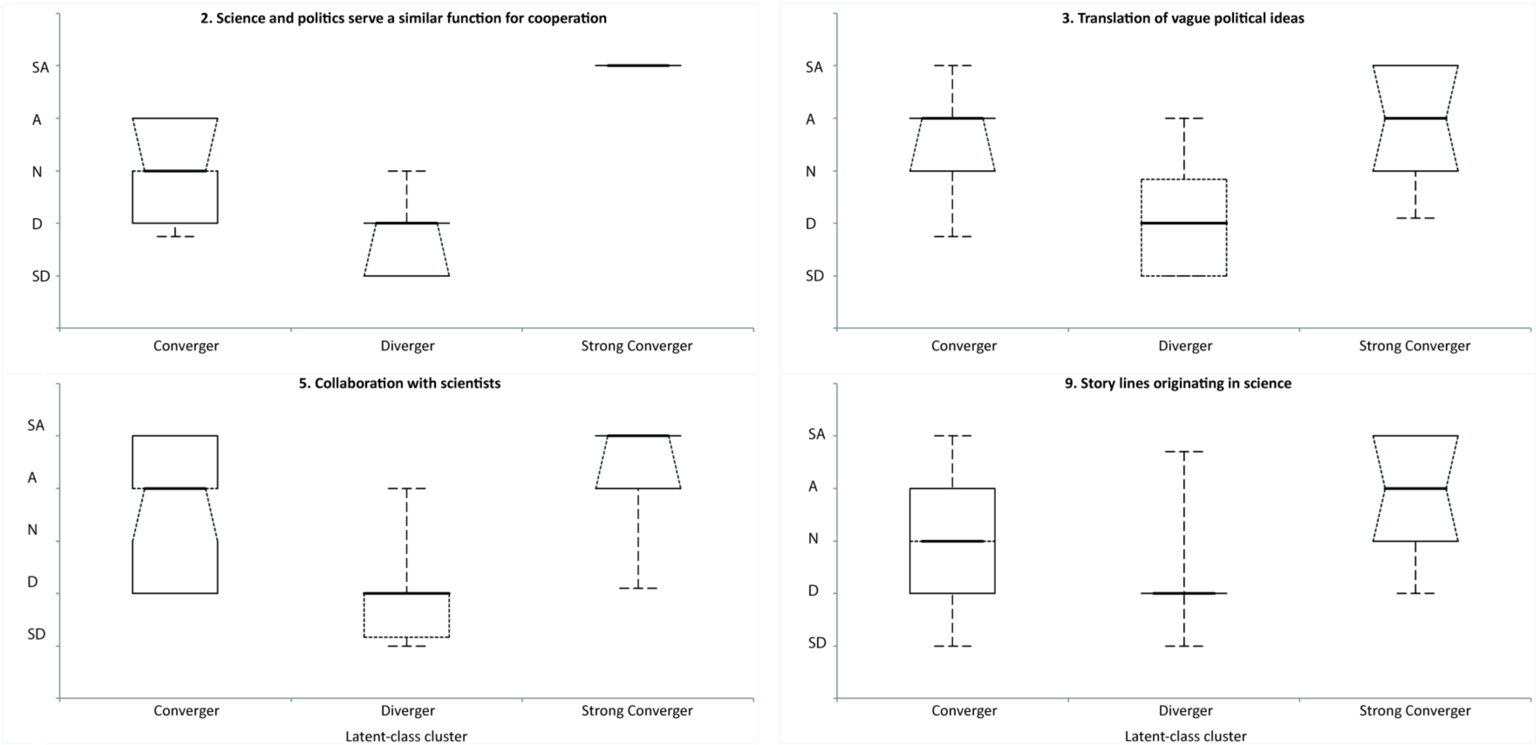


Professional values

We first ran latent-class models that included a maximum of eight clusters. The two-cluster model was within 2ΔAIC units of the model with the lowest AIC and had fewer parameters (S4). We sequentially deleted five statements from the latent-class cluster analysis to eliminate all significant bivariate residual coefficients. The four remaining statements were *science and politics serve a similar function for cooperation*, *translation of vague political ideas*, *collaboration with scientists*, and *story lines originating in science* (recall Table 2). We then ran latent-class models that included a maximum of four clusters. The two-cluster model had the lowest AIC. However, the level of support for the two- three- and four-cluster models was almost equivalent (ΔAIC=1.58). We elected to retain the three-class model (Model 11 S4) for further analysis; there was a 0.09 increase in entropy R^2 and a three-class model aligned more closely with the theoretical ideal compared to two- or four-class models.

In the three-class model, one cluster (68% of the respondents) consistently expressed a moderate level of agreement with converger statements (converger, cluster 1), one cluster (18%) consistently expressed a low level of agreement with converger statements (diverger, cluster 2), and one cluster (15%) agreed strongly with all converger statements (strong converger, cluster 3) (Figure 2). In the two-class model, by contrast, the converger and diverger clusters included about 77% and 23% of respondents, respectively. This shows that the choice of three-class model provided more explanatory power than a simple splitting of one group in half, as indicated by the entropy R^2 figure in the three-class model.

Figure 2 – Level of agreement by each of three latent class clusters with nine statements that could be used to differentiate convergers from divergers. SA, strongly agree; A, agree; N, neither agree nor disagree; D, disagree; SD, strongly disagree. Boxes include the first through third quartiles. Line, median ranking; capped bars, 5th and 95th percentiles. Full statements are in Table 2.



The null hypothesis that median ranks were equal for all statements was rejected (*S*=199.6, 8 d.f., $p<0.001$). The null hypothesis that median ranks for each statement were equal across the three clusters was rejected at the 1% level for all significant statements in the final latent class model (Table 4). Tukey post-hoc tests rejected the hypothesis that median ranks of statements in the final latent class model were equal between pairs of clusters at the 5% level in all but two cases. The exception was the converger and strong converger cluster, which did not statistically differ in their ranking of statement 3 (*translation of vague political ideas*, $p=0.829$) and statement 9 (*story lines originating in science*, $p=0.145$).

Table 4 – Difference in mean rating of professional attitude statements

Statement	Difference in mean rating across clusters[i] Krusal-Wallis *H*	Difference in mean rating between clusters (0-5 scale)[ii] Converger-diverger	Converger-strong converger	Diverger-strong converger
2. Science and politics serve a similar function for cooperation	61.50*	1.4*	-1.9*	-3.3*
	(0.000)	(0.000)	(0.000)	(0.000)
3. Translation of vague political ideas	27.02*	1.6*	-0.2	-1.7*
	(0.000)	(0.000)	(0.829)	(0.000)
5. Collaboration with scientists	28.63*	1.5*	-0.8	-2.3*
	(0.000)	(0.000)	(0.050)	(0.000)
9. Story lines originating in science	15.92*	0.9*	-0.6	-1.5*
	(0.000)	(0.003)	(0.145)	(0.000)

[i] Statistical significance in Kruskal-Wallis test in parenthesis. Rankings that were significantly different at the 1% level in Krusal-Wallis tests are denoted with *
[ii] Statistical significance in Tukey-Kramer post-hoc comparisons in parenthesis. Rankings that were significantly different at the 1% level in Tukey-Kramer post-hoc comparisons are denoted with *

Cluster membership differed significantly between respondents who were 50 years of age and older (n=56) and those who were under 50 years of age (n=70) (χ^2[4 d.f., n=126] =7.03, $p=0.03$). Older respondents comprised a higher percentage of the diverger cluster (25%) than younger respondents (8%). The majority of respondents in both age classes were convergers (73% of those under 50 years of age and 63% of those 50 years of age and older). The strong converger cluster included 19% of respondents younger than 50 years of age and 12% of those 50 years of age and older. Other demographic variables were not significant (S2).

Research orientation

The null hypothesis that median ranks of research priorities from the prior survey (Rudd and Fleishman, 2014) were equal among the current latent classes was rejected (*S*=1206.5, 39 d.f., $p<0.001$). However, of the 40 priorities from the prior survey, ranks differed significantly only for statement 7, *What are reliable scientific metrics for detecting chronic, long-term changes in ecosystems?* (H=6.4, 2 d.f., p=0.04).

Qualitative responses

Respondents' interpretation of some statements about science-policy boundaries differed considerably (Table 5). For instance, more than half (60%) of the comments about statement 3 (*translation of vague political ideas*) focused on respondents' beliefs that researchers have a responsibility to communicate science to policymakers, and that research should inform policy to a greater extent. The remaining comments about statement 3 (40%) stressed a perceived distinction between positivist science and value-based normative evidence used in policy. These comments represented a strong preference for science to provide 'objective truths' on which decisions can and should be based. Respondents who provided the latter comments perceived political decisions as "grey areas" characterized by "unsound actions" (ID256), "emotions," and "selfish/partisan motives" (ID256).

Fifty percent of the respondents who signified that statement 9 (*story lines originating in science*) was very important, characterized narratives as vital for gaining the attention of the public, "envision[ing] other groups' points of view" (ID636), and accommodating the "combination of values plus facts present in any decision" (ID1412). The other 50% of respondents to statement 9 asserted their belief that a "strong science foundation" is important for public policy (ID1143) or that "truth can only be proven through scientific discourse and research" (ID1412). Similarly, 31% of comments about policy-makers' collaboration with scientists (statement 5) conformed to the view that decision-making involves multiple inputs, "socio-economic as well as natural science" (ID1003). According to this view, "values and beliefs are as important as scientific evidence" (ID797). However, 28% of respondents interpreted statement 5 in a more divisive manner, asserting that expert knowledge provides the necessary basis for "science-informed policy" (ID1143) and that the only good decisions are those based on "sound evidence" (ID1326).

Comments about science and politics serving a similar function for cooperation (statement 2) were more homogeneous. Common words and phrases used by respondents included "compromise" (ID1361), "healthy debate" (ID1326), "effectiveness" (ID1326), and "common benefit" (ID1478). Respondents who agreed with statement 2 commented that "the shared goal of science and politics is to serve humanity, just phrased differently" (ID1326). This group did not tend to regard either science or politics as superior, but as "different ways of knowing (ID797), each "add[ing] elements to the process" (ID1003).

Table 5 – Qualitative coding of responses from individuals who agreed strongly with converger-diverger statements

Statement [i]	Number of respondents who agreed strongly with statement	Key phrases used to code responses	Number of coding observations [ii]	Percentage of coding observations	Examples of interpretations of the statement by respondents to this survey
1. Responsibility for disseminating the policy implications of research	5	• Traditional science-policy division of responsibilities	2	40	• Scientific enterprise generates the data - the best possible version of the truth at the time - the rest is up to the politicians (ID36) • Researchers need to focus on their research and let the policy-makers make use of it (ID1117)
		• Institutional barriers between science and policy	3	60	• The connection between scientists and policy-makers is such that each considers the other to have an inferior position and does not seek to bridge the gap with the other (ID36) • The academic system neither rewards nor promotes the application of research (ID385)
2. Science and politics serve a similar function for cooperation	18	• Compromise and debate • Different ways of knowing	18	100	• Scientists learn about how the world works to make it a "better place". Policy makers enact policies for the same reason (ID268) • Science-based political decisions generally promote agreement and cooperation because they transcend a partisan focus (ID1326) • Science and politics are different ways of knowing (ID797)
3. Translation of vague political ideas	27	• Communication duty beyond academia • Impetus for impact	16	60	• Basic research is valuable, however dissemination of research to decision and policy makers is essential for change (ID193) • Scientists need to communicate their work effectively for it to have impact in the social and political arena (ID1489)

		• Distinction between non-biased science and value-based political decisions • Policy should be science-driven	8	40	• Science by its very nature is non-biased. Political ideas are always biased. We must rely on science to inform decisions (ID918) • Politics thrive on grey areas as emotions can then advance unsound actions. Policy-makers don’t listen to scientists (ID256) • Leaders and policy-makers who ignore the "public good" results by science, will eventually embrace those results. Science triumphs bad, harmful politics and their practices in the end (ID1326)
4. One scientific discipline dominates	5	• Hegemony of a dominant discipline	5	100	• Other disciplines face an uphill battle to create a discussion convince the dominant discipline that their views have merit (ID363) • Economic endpoints seemingly always overshadow environmental benefits because we lack the ability to accurately quantify economic benefits of environmental protection (ID256)
5. Collaboration with scientists	36	• Collaboration, inclusion, participation • Multiple inputs to decision-making	11	31	• Collaborative management should involve all stakeholders, and scientists/researchers are stakeholders (ID1457) • Scientists and bureaucrats must collaborate, as bureaucrats must deal with politics and policy-making. Values and beliefs often conflict with science and both values and beliefs and science are important (ID797)
		• Policy-maker obligation to deliver science-informed policy	10	28	• Good sound science provides solid evidence for decision makers (ID256) • If you're not basing policy decisions on sound science, and/or working to ensure that policy decisions will not have unintended consequences for the resources in your care, you are not exercising the due diligence required (ID463)

		• Communication duty	4	11	• Scientists need to see that their work in natural resources is meaningless unless they find a way to work with administrators on policy implementation (ID797)
		• Science-informed policy rarely happens in practice	6	17	• Good policy is based on reality - science provides the foundation for effective decision making; the alternative - policy by whim or political agenda, is generally guaranteed to fail (ID256)
6. Uncertainty reduction through science	4	• Comfortable with uncertainty	2	50	• Uncertainty is a fact of life. Learning occurs through trial-and-error and there are no perfect, certain answers (ID1478)
		• Uncertainty leads to exploitation and opportunism	2	50	• Political conflicts can often make situations worse (ID1156) • It is easy for someone to use science to "justify" a particular policy viewpoint (ID492)
7. Policy learning is limited	7	• Bias towards economic and scientific evidence	5	71	• I don't see evidence that policy-makers weight scientific evidence as much as economic or other political convictions (ID61) • Politicians or policy makers are motivated to learn only when it comes to financial and organization matters, and are not concerned with learning or understanding scientific concepts or study interpretation (ID191)
		• Exploitation by lobbying interests	2	29	• There is no complete freedom of speech and thus good environmental solutions are tempered by government officials, banks and others, some who are highly influenced by anti-Green, anti-environmental, deep-pocket interests (ID191)
8. Uncertainty reduction through political debate	24	• Misunderstanding of uncertainty	4	17	• Politicians seem to equate uncertainty with shoddy science, when that isn't the case (ID1117) • Both scientists and policymakers are guilty of downplaying uncertainty in assumptions that underlie their recommendations (ID264)
		• Exploitation of	4	17	• Uncertainty gets abused in the political debate - politics

		uncertainty			exploits uncertainty dishonestly to gain political advantage (ID466)
		• Uncertainty is a vital part of any decision-making process and requires full disclosure	16	67	• Thorough and honest political debate free of prejudice and myth and based on reality quantified by statistics and research will lead to rational decision making (ID1052)
9. Story lines originating in science	16	• Narratives pass the ‘so what’ test	8	50	• Stories are easy ways to help groups envision other points of view (ID636) • Human beings make decisions and take action based on a combination of values plus facts (ID1123)
		• Powerful because they are evidence based	8	50	• Science is needed for all policy development (ID645) • Truth can only be proven through scientific discourse and research (ID1117)

[i] Value statements retained in the latent class analysis are in boldface.

[ii] Instances that this key phrase was coded in qualitative analysis (maximum one coding observation per respondent)

Discussion

Survey responses

Results of our survey indicated the presence of three groupings of personal values. Clusters 2 and 3 were almost indistinguishable in the high importance they gave to biospheric and altruistic values. Combined, these two clusters made up almost 60% our sample. This suggests that the value of preserving the natural world is of high importance to actors in natural-resource policy and management in the United States [27]. Respondents in the first cluster were notable for the importance they placed in self-enhancement values like authority and influence, as well as openness to change, in this case having variety in one's life. These individuals attached much lower importance to biospheric values, and gave lower importance to altruistic values. This combination of values suggests that these individuals are more interested in satisfaction of their own goals than those of others [29,30]. This position was particularly strong with regards to the environment, which consistently failed to create a strong sense of importance among this group.

Environmental advocates and *environmental supporters* differed in the importance individuals attached to authority and influence. *Environmental supporters* attached very little importance to having authority and low importance to influence and impact. *Environmental advocates*, on the other hand, attached moderate to high importance to having influence. The question is: why did this desire for impact affect only a proportion of those with biospheric values? This point of cleavage between two groups with high biospheric values may reflect a potential inconsistency in the personal value scale. Personal authority and influence are classified as self-enhancing or egoistic in Schwartz's value scale, and inversely related to biospheric values in the literature [31,42]. However, there is a suggestion from our results that in areas where individuals have strong feelings about the importance of preserving the natural environment, there will be, among some, an imperative to intervene to protect it through environmental conservation and natural resource management. In this situation, the importance of influence and impact may be motivated by altruistic urges to improve an external situation, rather than by self-enhancement. The potential ambiguity between the altruistic and egoistic motivations of influence and impact may suggest that the scale of universal values does not distinguish reliably between personal and professional values. In this context some modification of scale items may be required to remove the dichotomous relationship it implies between self-enhancement and other-enhancement values [31,42].

Results of our survey suggested that attitudes about relations between science and policy differ significantly among actors in natural-resource policy and management in the

United States. Respondents grouped into three classes (diverger, converger, strong converger) on the basis of their agreement or disagreement with statements characteristic of convergers or divergers. The largest cluster of natural resource scientists, managers, and policy-makers in the United States tended to agree modestly with statements characteristic of convergers [28], who see policy and science as collaborative and integrated. In Hoppe's original factor analysis, modest converger beliefs were associated with *policy advisors*, "the bureaucratic counterpart to the role of a knowledge-institute based policy analyst" [8 p.249]. Attitudes around the *translation of vague political ideas* were distinguishing for this factor [8]. Modest convergent beliefs were also characteristic of *postnormalists*. Postnormalism is a methodology of inquiry that is appropriate for cases where facts are uncertain, values in dispute, stakes high and decisions urgent (Funtowicz and Ravetz, 1991). Postnormalist boundary workers were distinguished by a complementary view of science and politics, but saw convergence as "more of a desire or aspiration than a reality" [8 p.250]. They were also "influenced by and attracted to a conception of interdisciplinary science" [8 p.250]. It seems likely that the converger cluster in our analysis shared elements of both policy advisor and postnormalist factors from Hoppe's analysis. Our sample (n=126) was much larger than Hoppe's (n=22), which might account for the blurring of lines between professional affiliation and distinguishing science-policy factors.

Use of a three-class rather than a two-class model allowed identification of an additional group that agreed strongly with converger statements. This group is likely to be strongly related to the *deliberative proceduralists* identified by Hoppe [8]. This was the strongest group of "articulate and consistent convergers" in the Hoppe analysis [8 p.251]. In common with our strong convergers, they were distinguished by the statements that *science and politics serve a similar function for cooperation*. They were "even more strongly idealistic about convergence than postnormalists" according to the agreement they gave to converger statements, and stressed the importance of acknowledging normative issues in decision-making [8 p.252]. However, deliberative proceduralists were also highly comfortable with scientific uncertainty, which was not present in our final models. In our sample, differences in science-policy attitudes were not associated with any professional or disciplinary affiliations. This suggests that there were considerable commonalities along the spectrum of converger-diverger attitudes across a broad sample of professional affiliations.

Generational differences

The converger-diverger dichotomy was partially explained by age and may reflect a generational shift in perspectives about the role of research in policy [43]. It appears that relatively young researchers and policy-makers are familiar with calls for greater integration of science and policy [5,11,12], and some members of each sector actively are collaborating with members of other sectors. Our results are consistent with claims in the transdisciplinarity literature that younger researchers and policy-makers are keen to work across traditional disciplinary and sectoral boundaries [47,48].

Jacobs and Nienaber [48] compared the traits of a stylized, ideal transdisciplinary researcher with the traits of the younger working generations (born after 1965). Many of the characteristics of the postnormal and transdisciplinary researcher matched with attitudes of both the younger generation and convergers. Attitudes and attributes of younger generations, such as openness to change, familiarity with technology, and team-oriented education and work experiences [49,50], were regarded as compatible with team science and network approaches to research. The latter approaches are consistent with transdisciplinary principles [16–18] and characteristic of converger perspectives [8,28].

Alternatively, converger and transdisciplinary aspirations could be characterized as idealistic or even naïve. These aspirations may reflect optimistic youth, whereas the diverger attitudes of the older generation may reflect political realities. In this sense, we do not think diverger attitudes should be characterized as negative or reactionary, but instead as the product of collective experience at the science-policy interface. Diverger attitudes also could be a reaction to the barriers and transaction costs associated with closing the gap between sectors and disciplines, and the limited perceived benefits of doing so [25]. If experience has shown the difficulties involved in bridging the science-policy gap at the practical level, then this may lead to a rejection of converger attitudes, and a hardening towards calls for cross-sectoral and crossdisciplinary integration.

Caveats to analyses

Up to three models of personal value and science-policy attitudes were equally well supported by the data. The literature suggests that selection of the final model should be informed by the research question [35,36,51]. Context affects which method best explains variance in the data [38]. Given our small sample, our intent was not necessarily to identify the most parsimonious model, but to compare alternative models of personal values or agreement with converger and diverger attitudes. For example, the diverger group was identified in both the two- and three-class models, whereas a three-class model differentiated between moderate and strong converger attitudes.

Our results are consistent with previous suggestions [26] that converger and diverger attitudes are best conceived as ends of a spectrum rather than as a dichotomy. By contrast, Hoppe found that distinctions between converger and diverger attitudes were unclear [8]. Differences between our methods and those of Hoppe [8] may have contributed to differences in results of the two studies. Hoppe sampled from within general economic, environmental, and strategic boundary organizations in Europe, whereas we sampled from a narrower range of disciplines (natural resource management) in the United States. Additionally, Hoppe's sample included scientists (n=9), policy-makers (n=7), and boundary workers (n=6) [8]. Our sample included scientists and policy-makers. We did not classify respondents as boundary workers, but we sampled individuals with more diverse affiliations than did Hoppe. Therefore, our results were more representative of the range of actors in natural resource management and were specific to the United States [52].

We did not find consistent differences in research priorities among latent classes. As a result, we cannot identify determinants of the differences in research orientation that Rudd and Fleishman [27] identified in the previous survey. The fact that clusters were differentiated on the basis of personal values is consistent with the results of previous prioritization exercises [e.g., 53] and literature suggesting that one's background affects one's perceptions of the role of evidence in policy making [5,53,54].

The group that selected and prioritized research questions in the previous survey [27] was dominated by science advisors versus classically defined policy-makers. We captured the attitudes of a relatively large number of policy-oriented individuals employed by government (n=19), so we were satisfied that their perspectives were represented adequately. The significantly lower proportion of respondents with terminal Bachelor's degrees in our sample and the significantly higher proportion with postgraduate degrees may imply a self-selection bias. It is possible, for instance, that those with postgraduate scientific training were more willing to complete the survey.

Personal and professional values

We rejected both the hypothesis that there were no differences in attitudes about the interface between science and policy among our sample of scientists and policy-makers in the United States, and the hypothesis that there were no differences in underlying values among respondents. Professional attitudes were explained by demographic variables, which suggested that the groups we identified may occur not only in our sample but in the population (Burnham and Anderson, 2004; Vermunt and Magdison, 2002). Personal values were cleaved at 60/40 between environmental and self-enhancing values, but did not provide any further insights into why respondents chosen certain research priorities, or what professional or demographic factors drove this difference in personal value priorities.

Rudd and Fleishman [27] suggested that attitudes about the science-policy interface may play a stronger role in shaping research priorities than professional and demographic characteristics. Professional attitudes were more distinctive in our sample than personal values, showing cleavage in line with that expected from the literature [8], and displaying significant differences between age groups. However, other factors could have contributed to the outcomes of research prioritization. Both the Rudd and Fleishman survey [27] and this survey followed a process that explicitly encouraged participants to consider the policy applications of research and the role of evidence in the decision-making process. Dietz et al. [54] found that deliberation of willingness to pay for policy change led survey respondents (citizens) in the United States to assume the role of policy analysts who consider costs, benefits, and the feasibility of implementation of such changes. They concluded that "even minimal group discussion prompt[ed] citizens to think in terms of public values" [54 p.344]. Research prioritizations and follow-up exercises may prompt similar thinking among scientists.

Behavioral psychology literature [55–57] suggests that the context in which a respondent is asked to prioritize research normalizes policy considerations [58]. If the framing of the prioritization exercise implicitly assumes that research should inform policy, then the probability of policy-oriented answers may increase [59]. In contrast, a prioritization process that emphasizes research independent of its applications may elicit different responses from the same group of participants [60]. It may have been the case that agreement elicited for impact and influence on the personal value scale was partly driven by the frame of natural resource management considerations. This may have led those with strong beliefs around environmental protection to attach high importance to impact, with a view to professional and policy considerations, rather than their personal self-enhancement. We recommend that future research-prioritization exercises take into consideration the effects that a policy-oriented deliberative process [61] may have on outcomes. Our results raise additional questions about the links between personal values and professional attitudes and the extent to which either affects priorities for research on management of natural resources. It may be worthwhile to incorporate these questions into tests comparing individualistic and deliberative research prioritization processes in the future.

Conclusion

Personal values and professional attitudes explain some of the differences in research priorities. However, these differences were homogeneous across professional (research and policy) affiliations. This leaves open the question of what drives attitudes to the science-policy interface, and how these interact with research prioritization in the knowledge coproduction process. Nevertheless, there was evidence of a generational split between strong convergers and moderate converger attitudes. Overall, converger attitudes predominated, suggesting that transdisciplinary and post-normal approaches to the generation and application of evidence have gained considerable acceptance in the natural resource management field.

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Chapter VI Thesis conclusion

Ricky N. Lawton

Introduction

The scale and depth of human impacts on the environment moves towards its twenty-first century peak. Mass species extinction (Barnosky et al., 2011), catastrophic climate risks (Weitzman, 2011), and natural resource depletion (Browning, 2013; Deffeyes, 2008) impose constraints on economic productivity, human well-being and the quality and health of biotic and abiotic systems (Hassan et al., 2005). Resource and time constraints put a premium on research, policies, and interventions with clear and direct impact (Jones et al., 2009; Lawton, 2007).

The focus of previous research impact literature has been on the role of evidence in policy-making, and how this can be improved for environmental objectives (Cortner, 2000; Neßhöver et al., 2013; Owens, 2005; Sutherland et al., 2012; Watson, 2005; Young et al., 2014). However, additional questions arise when one considers the pathways of conservation science into environmental policy. The development of an 'ecosystem approach' in UK policy was an instructive case. A range of non-evidentiary influences were identified, including the gradual accumulation of academic thinking, windows of opportunity presented by political circumstances, the influence of vested interests, and the personal energy of issue advocates and politically engaged experts. The difficulty arises in disaggregating the impact of any one piece of evidence from the array of other influences (Davies et al., 2005; Griliches, 1998).

In this thesis I took up the challenge of analyzing the impact of evidence on the policy-making process with attention to the contextual factors that affect its uptake and influence. An important issue flagged by the funder of this research was that "the context in which research messages are communicated has a bearing on their possible impact" (ESRC, 2009, p. 15). Context is a broad term that may apply to political factors, policy processes, institutional structures, public perception, public values, belief systems, norms and regulations that exist in the coproduction of knowledge (Jasanoff, 2004; Jasanoff and Wynne, 1998). These may be defined as the *non-evidentiary* factors present in the social or political arena, which affect the receptivity of scientific research. Their influence is an important driver of what evidence is taken into account in policy decisions, and forms the circumstances in which scientific knowledge is or is not able to influence policy outcomes (Pettigrew, 2011). The wider societal or policy context consists of *intermittent variables* - factors occurring at irregular intervals and in varying quantity - affecting the utilization of evidence on the policy process. The challenge in this thesis was to make these processes visible: to deshroud the black box of evidence use in the policy process.

This thesis focused on two substantive policy areas. The first, biodiversity loss, as outlined in Chapters II and III, was of interest because the rise of ecosystem approach and ecosystem services solutions in the past two decades is of great interest from the perspective of research impact on policy. The second area of natural resource management (Chapter V) provided a comparison study on the role of science in policy and, specifically, the role of science-policy actor attitudes and values on research and management priorities.

Research utilization literature theorizes three types of research impact: instrumental, diffuse, and conceptual/symbolic impact (Weiss, 1979). Instrumental impact refers to the direct influence of scientific evidence on political decisions (e.g., the discovery of disease pathways such as those linking cholera to drinking water in the 1850s), material production (e.g., biomedical patents and electrical-engineering inventions), and academic research (the insights of one research output directly informing further advances in research). However, impact does not have to be immediate to have value. Diffuse impact entails a progression of human understanding through the gradual accumulation of new information, contributing to the overall 'Agora', or library, of human knowledge (Frederiksen et al., 2003; Weiss, 1979). A newly patented biomedical discovery is only made possible through decades, if not centuries, of accumulated research across multiple disciplines and researchers. Also referred to as 'knowledge creep', the process of research impact is diffuse and spread over time and place, meaning that direct lines of causal influence are not easily identified (Weiss, 1980). For policy impact, the paths of influence for new evidence on political beliefs and public attitudes are more nebulous, with many interactions, steps changes and paradigm shifts affected by social, cultural, and cognitive processes that we are only recently coming to understand (Contandriopoulos et al., 2010; Earl et al., 2001; Pettigrew, 2011).

Assessing research impact in the political sphere requires consideration of the strategic or symbolic use of evidence (Amara et al., 2004; Knorr, 1976). It has long been recognized that scientific evidence may be adopted by policy actors for the purposes of argumentation and political negotiation (Bimber and Guston, 2002; Collins and Pinch, 1998; Hoppe, 2011; Weiss, 1991). Traditionally, scientific researchers have been uncomfortable with the idea that evidence may be used for strategic or symbolic purposes, perceiving this as a 'misuse' of evidence (see e.g., the study of researchers' attitudes on the UKNEA, Waylen and Young, 2014). Characteristic of *enlightenment* models of science, evidence produced by scientifically-trained researchers is perceived to be objective and credible, while what is debated in the political sphere is portrayed as subjective and biased by the interference of personal values and group interests (for further discussion, see the literature on boundary work, e.g., Fisher, 1990; Gieryn, 2008; Jasanoff, 1987; Yearley, 1988).

I start from an alternative premise. The strategic use of evidence is a long-standing and important application of scientific evidence to a non-expert arena. Evidence of the state of the world 'out there' is one of many inputs into the negotiation of societal choices and decisions (Wittrock, 1991). Human decisions involve evidence and judgements on complex and often non-linear processes from the natural and human worlds (Latour, 2013; Reid et al., 2010). Decision-making requires socio-ecological knowledge that incorporates better understanding of the science behind natural processes in societal decisions (Folke et al., 2007; Liu et al., 2007). However, research impact of this kind requires scientific researchers approach the decision-making arena with better understanding of the 'rules of the game'. Conservation scientists can benefit from concise descriptive tools to map contextual factors that affect the use of their evidence in decision-making. That means an appreciation that science is not the only 'truth' that decision-makers hear (Habermas, 1985). It also means an appreciation that science itself is subject to differences in interpretation, institutional and interpersonal biases, and paradigm shifts in consensus that belie the traditional enlightenment view of objective and rational science (Kuhn, 1962).[9]

Impact at the policy level should be understood to operate through strategic means. The utilization of knowledge for policy purposes takes the form of discourse narratives that interpret, frame, and engage scientific evidence for strategic and symbolic purposes. Attempts to understand and assess strategic impact have been limited to date. Consequently, we lack methodological tools to capture the ways in which evidence interacts with social and policy factors. Across the course of this thesis I tested a range of approaches to capturing the strategic use of evidence in the policy process through the influence of contextual factors. This conclusion provides assessment and comparison of the theoretical and methodological insights of a range of frameworks and approaches of relevance to the science-policy interface. The research presented in this thesis outlines the strengths of weakness of different methodological approaches to capturing contextual impact, and provides lessons to improve the impact of research projects and assessments going forward. In this way it should be

[9] From the perspective of science-policy impact assessment, expert-based knowledge presents as many truths as there are audiences to receive and interpret information. Cognitive psychology has demonstrated how individuals' pre-existing values and beliefs act as filters, changing the way in which new information is interpreted and assimilated into our prior patterns of thought (Lord et al., 1979; Munro and Ditto, 1997). The insights of discursive and narrative frameworks of the policy process recognize the necessary part that narrative construction plays in the dissemination and utilization of evidence (McBeth et al., 2014; Yanow, 2007). Scientific narratives, therefore, have many authors, both in terms of the researchers that produce them, and the audience that receives them (Gerrig, 1993; Gibbs Jr. and Gerrig, 1989; Jauss, 1982; Miall and Kuiken, 1994).

possible to identify commonalities in intermittent contextual variables across different case studies. This allows consideration of success factors to enhance the impact of research outputs across multiple policy contexts.

I outline my key findings with reference to case studies from the wider literature and real-world examples of direct relevance for science-policy going forward. Chapter I applied integrated environmental assessment (IEA) and Team Science methods to the case study of research production for ecosystem assessments across multiple disciplines and sectors. Chapter II, III and IV applied Advocacy Coalition Framework (ACF), discourse analysis and narrative policy approaches to assess the role of evidence and influence of contextual factors like group interests, individual influence, entrepreneurial activity and public receptivity in the case study of political consultation and policy development around the UK Natural Environment White Paper. Chapters IV and V explored the role of values, attitudes and beliefs in the prioritization of research evidence for policy implementation.

I present the insights from this thesis as a set of practical recommendations for designing future research projects with the aim of increasing the impact of conservation science on the policy sphere. These include discussions of the entrepreneurial impact of the Stern Review of Climate Change, and the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES).

Synthesis papers

Contextual analysis of the Natural Environment White Paper (2011) policy system in Chapter III identified the power of synthesis reports for increasing the impact of research on policy. The UK National Ecosystem Assessment (*UKNEA*, 2011) and Making Space for Nature (henceforth, *Making Space*, Lawton, 2010) were perceived to be the most influential evidentiary inputs into the White Paper (Chapter III). These reports provided:

- Critical synthesis of a body of evidence or literature;
- Compared and contrasted methods and findings;
- Provided outputs that combined the constituent elements of separate material or abstract entities into a single or unified entity.

Large-scale assessments and syntheses of evidence are important venues for understanding the coproduction processes behind evidence impact (Sarkki et al., 2013; Waylen and Young, 2014). The heightened impact of synthesis reports was provided by their combination of credibility, expert composition, and policy relevance. Government and independent research institute reports were second most influential. Academic and single-author papers were least influential. There are a number of possible reasons for these findings:

- Policy-makers may be risk averse to new information (Fischhoff, 1995). Synthesis reports that are large in scale and involve multiple actors from different scientific disciplines and professional backgrounds suggest expert consensus. Agreement and sign-off from multiple expert and practitioner sources alleviates some of the concerns that can accompany new information (Finucane et al., 2000; Fischhoff, 1995). This shortens the risk of utilizing this evidence in policy;
- The process of preparing synthesis and independent research reports is deliberative and relatively transparent. Interim reports, steering group oversight, and stakeholder presence are common. These deliberative processes are familiar in format to policy reports. In contrast, the specialist methods of academic research and scientific peer-review rely on the expertise of a small number of specialists, are presented in restrictively technical terms, and follow disciplinary norms that may be unfamiliar to the outside or non-expert. The familiarity and comprehensibility of synthesis reports increases the likelihood of policy-maker utilization;
- Synthesis papers create their own networks of communication and influence. The transdiciplinary inclusion of practitioners and policy-makers from the earliest stages of research development mean that a receptive and engaged audience is already created for the report. As such, synthesis reports operate as science-policy interfaces in their own right, creating the pathways to wider impact through personal and conceptual linkages they form;
- Synthesis reports present evidence in simple policy-friendly form. The audience for synthesis reports differs from those of academic papers and specialist reports. Synthesis reports provide comprehensive reviews of data, rather than cutting edge innovations and new findings. Methodological advances, theoretical foundations and disciplinary criticism take second place to compelling narratives, conclusions and policy recommendations;
- Policy impact is achieved by use of jargon-free language. This improves lay practitioners and policy-maker understanding, reducing barriers to understanding and communication.

Case study one: Large-scale synthesis reports and assessments

The process of synthesizing, translating, and packaging diffuse knowledge from the research community for policy audiences is a prime venue for exploring the trade-offs in credibility and salience. As demonstrated in Chapter I, ecosystem assessments are important venues where researchers seek wider impact through collaborative crossdisciplinary research coproduction. Not all assessment reports are the same. Objectives for policy relevance, disciplinary integration and stakeholder involvement vary (recall Figure 1, Chapter I). It follows that synthesis reports do not experience the same impact. It is informative to compare three examples of large-scale ecosystem assessments from recent years: the Millennium Ecosystem Assessment (MEA 2005); the UK National Ecosystem Assessment (UKNEA, 2011); and the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES). It is important to note that IPBES is not an assessment, but an international work programme agreed upon by signatories from the United Nations. Therefore, while assessments are being undertaken in IPBES, it is in itself an intergovernmental process. Notwithstanding, the experiences of the MEA and NEA can help to inform assessment of the IPBES. There are also common policy actors across the three projects, most notably the entrepreneurial input of Professor Bob Watson.

Millennium Ecosystem Assessment

- International project combining multiple jurisdictions, research organizations and disciplines;
- Leadership board composed of scientists and institutional representatives;
- Natural and social sciences working collaboratively to quantify the products and functions of biodiversity elements, specifically ecosystem services, or benefits received by society thanks to the functioning of ecosystems (Larigauderie and Mooney, 2010);
- Aim: to develop the basic science needed to assess, project, and manage flows of ecosystem services and effects on human well-being (Carpenter et al., 2009);
- Exposed strengths and gaps in the underlying science, measuring the effects of policy choices and human actions on the structure and processes of ecosystems;
- Represented a paradigm shift by synthesizing knowledge in terms of the dynamics of coupled social–ecological systems, as well as exploring the relationships of ecosystem services and human well-being.

UK National Ecosystem Assessment

- National interdisciplinary report bringing together over 300 UK scientists;
- Leadership board composed of academics and government scientists;
- Developed with the inclusion of a large number of policy and practitioner actors at all stages of the research process. However, as noted in Chapter I, it was still a long

way of the integrative objectives of transdisciplinary research;

- Designed and developed through close connections with Defra, particularly the entrepreneurial work of Professor Watson;
- Aim: Comprehensive synthesis of ecosystem evidence across diverse habitat types within the UK, identifying gaps where necessary;
- Policy scenarios for six different conditions of future economic and social development (Haines-Young et al., 2011). The scenario approach applied robust-decision-making (RDM) principles, whereby science is called upon to provide information for multiple policy options (Lempert et al., 2010; Regan et al., 2005);[10]
- Offered a further paradigm shift in thinking by accentuating the potential for quantification of ecosystem processes within the ecosystem service paradigm;
- Ecosystem service valuation objectives lay at the heart of the classification system presented in the UKNEA, and underlay the increasingly economic language in which policy options were presented in the final third of the report.

Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services

- Intergovernmental work programme agreed upon by political signatories, providing a mechanism recognized by both the scientific and policy communities to synthesize, review, assess and critically evaluate ecosystem evidence;
- Aim: Strengthen capacity for the effective use of science in decision-making at all levels (Dubois, 2014). Synthesis of evidence, no undertaking of new research;
- Aim: Identify policy-relevant tools and methodologies. Prioritizing scientific information for policymakers and encouraging dialogue with key scientific organizations, policymakers and funding organizations;
- Following the IPCC it aims to be intergovernmental nature, ensuring that governments request the scientific information produced and approve it by consensus, making the reports legitimate and their results more likely to be used;
- Credibility was at the heart of IPBES, with stated aims of scientific independence and credibility, relevance and legitimacy through peer review and transparency in its decision-making processes (IPBES, 2014).
- Objective to provide an "IPCC-like mechanism for biodiversity" with policy-relevant information, but not policy-prescriptive advice (Larigauderie and Mooney, 2010, p. 9).

[10] Under RDM, expert opinion does not offer a preference for either, but only offer probabilities and likelihoods of certain outcomes under each set of scenario conditions.

A matter of degrees – Is there an optimum level of disciplinary integration?

Assessment of national and international ecosystem assessment projects raises a number of issues of relevance for future large-scale scientific research. What pathways to impact are most appropriate for different research, policy, and communication objectives? Who is the target audience and how can projects increase the receptivity of information to them? What level of disciplinary integration is most appropriate for the constraints, demands and objectives of each research project? What success measures would we use to deliver our impact objectives, are they all needed and in what degree? Trade-offs exist between the complexity of knowledge production and policy salience in terms of its presentation of data, uncertainties, and distinct disciplinary epistemologies, methodologies, and conceptual underpinnings. I explored methodological approaches grounded in Integrated Environmental Assessment (IEA) and compositional analysis.

- **Lesson 1: To achieve genuine transdisciplinarity, projects must overcome the barriers created by the delineation of research responsibilities into theme-based chapters. The challenge is to achieve this while acknowledging trade-offs of costs and benefits from disciplinary integration.**

Quantitative measures of researchers' participation in projects by their discipline and subgroups provided compositional indicators of disciplinary integration in day-to-day working practices (Evely et al., 2010; Stokols et al., 2008). This was further extended to include communication behavior and interactions at the interpersonal level. This provided important insights, for instance, the identification of chapters in the UKNEA that were compositionally low in disciplinary integration, and also low in interpersonal knowledge 'borrowing' between disciplines. This identified possible problem areas, where interaction between experts from different disciplines was obstructed by the structure of the project.

Both the MEA and UKNEA were developed in chapter format, with each chapter composed of researchers, in some cases from the sample discipline, in others broader disciplinary backgrounds, as well as individuals from policy and practice. The evidence from these separate chapters was brought together in synthesis chapters by core authors. As noted in Chapter I, this provided the structure and decompartmentalism required to achieve research on such a large scale.

The compositional approach applied in Chapter I may have failed to capture the stated aims of each chapter. It is important not to assume that each element of large-scale environmental assessment projects require the highest levels of disciplinary integration. In some cases, it may be appropriate for research or synthesis work to operate within narrow disciplinary confines, for instance, where outputs are intended to inform narrow evidence-based research questions, or the stated aim is scientific rigor and comprehensiveness over public communication and policy salience. There may be a place for 'disciplinary hegemony' in some elements of the research production process. The more important question is where crossdisciplinary efforts are focused. This is dependent on the impact objectives and stated aims into crossdisciplinary assessment efforts. Piloting should collect qualitative data on disciplinary integration and wider impact objectives, in order to construct clear success targets for crossdisciplinary team science initiatives through survey, interview, observational, and archival measures (Stokols et al., 2008).

I found evidence of barriers in the production of evidence. Partly these related to the differing methodological backgrounds of the evidence being synthesized within the UKNEA. The conditions for collaboration between scientists were demonstrated to be in a large part social, or procedural factors like communication and facilitating arrangements, and structural factors like project leadership (Lawton and Rudd, 2013a). These findings were in line with other analyses of the UKNEA as a site in the production of environmental evidence (Waylen and Young, 2014). It also accorded with Science and Technology (STS) theory that was applied to subsequent chapters in the thesis (Jasanoff, 2004; Jasanoff and Wynne, 1998). Conservation science research, even in the production phase, was found to be multi-faceted, complex, and dependent on a range of contextual social and procedural factors (Dunlop, 2014; Jasanoff and Wynne, 1998; Yearley, 1988).

➢ **Lesson 2: Dialogue with policymakers requires the transdisciplinary inclusion of non-academic experts, practitioners, and policy-makers throughout the research production process.**

As detailed in Chapter I, the highest level of knowledge production is often defined as transdisciplinarity (Aboelela et al., 2007). Transdisciplinary research can be divided between shallow transdisciplinarity, aiming to transcend the epistemological and methodological differences between disciplines at the conceptual level (Lawrence and Després, 2004; Nicolescu, 2006; Wickson et al., 2006), while full transdisciplinarity incorporates policy actors and practitioners at all stages of research production (Jahn et al., 2012; Lang et al., 2012; Nowotny et al., 2001).

- Each approach has associated transaction costs, not only in terms of facilitating arrangements, but also in reduced communicability to non-academic audiences (recall Figure 1, Chapter I);
- There are also differences in benefits. For instance, Chapter I found evidence that "methodological hegemony could be seen as a good thing from the perspective of policy impact" since it allowed a simple, single viewpoint to be advanced to policy-

makers, which simplifies the knowledge communication process (Lawton and Rudd, 2013, p. 155). Multiple epistemological and methodological inputs, in contrast, may heighten the sense of fracture and disagreement, giving the impression of a ‘wicked’ policy problem area (Sarewitz, 2004). As noted earlier, policy-makers are attracted by the impression of consensus, since it reduces the risk of controversy associated with choosing a policy decision based on evidence;

- The inclusion of policy-makers and practitioners brings optimal returns to investment in the research production process. Full transdisciplinary inclusion of practitioners and policy-makers from the earliest stages of research development ensures a receptive and engaged audience. However, these benefits depend on the context in which assessments take place, and the impact objectives of the research output.

The MEA provides direct lessons for the IPBES. The IPBES is not designed to feed into a specific policy instrument in the UKNEA model. IPBES does not undertake additional research or address key research gaps as the MEA and UKNEA did. The main domain where scientists will be active is that of knowledge generation, which will be performed outside of, but in close connection with, IPBES (Larigauderie and Mooney, 2010). In this way IPBES is designed to operate much more as a science-policy interface than the UKNEA, “organizing a dialog between governments and scientists, and in focusing and structuring the international research efforts around a set of common products” (Larigauderie and Mooney, 2010, p. 13). This makes IPBES a particularly salient case study for the role of transdisciplinary integration in science-policy interface activity.

- **Lesson 3: Incentives should be introduced, both professional and financial, for researchers to participate over a longer period in large-scale assessment projects.**

Disincentives to successful collaborative working may exist within academic institutions (Trochim et al., 2008). Contributions to large-scale scientific assessments may not be considered in traditional academic impact assessments, despite their scientific and policy relevance. Even the recent reforms to the Research Excellence Framework (REF) in UK classify work on independent reports of this type as ancillary (Owens, 2013; REF, 2011). As such it is valued less in the assessment of academic excellence than individual papers in academic journals. Yet, as shown in Chapter III, academic papers often have lower impact on policy than independent synthesis reports. Furthermore, researcher and policy-maker contributions as authors are not paid, and may be subject to a number of practical and procedural barriers that limit disciplinary and transdisciplinary integration (Lawton and Rudd, 2013; Waylen and Young, 2014).

Do convergers have more impact? An examination of convergent attitudes to science and policy

The prioritization of research, management, and policy interventions is an additional venue for assessing the role of non-evidentiary factors on the knowledge coproduction process. I found that researcher attitudes to the science-policy interface differed between respondents based on age (Chapter V). However, questions remain about the types of attitudes that prevail, and their influence on evidence impact and utilization. In particular, does the prevalence of converger attitudes towards the science-policy interface – those that work as if there is no gap between evidence and policy – lead to greater impact for the research project? What effects should we expect the presence of converger/diverger to have on a research project? Do diverger attitudes lead to lower impact and outreach efforts, affecting the policy salience and broader influence of research outputs?

Converger attitudes, such as openness to change, familiarity with technology, and team-oriented education and work experiences (Camerer et al., 2004; Guha and Martinez-Allier, 1997), may be regarded as compatible with integrated environmental assessment and network approaches to research, consistent with transdisciplinary principles (Balvanera et al., 2006; Navrud and Ready, 2007; UKNEA, 2011). Diverger attitudes are typically held in opposition, as emphasizing the gap between science and policy and assuming that science and policy are largely incompatible (Wittrock, 1991). However, it is important not to assume that diverger attitudes are regressive for the purpose of research impact. Diverger attitudes may be beneficial to research production, operating as a complementary balance to converger viewpoints.

The optimum converger/diverger composition on a research project may include a range of researchers with both converger and diverger approaches to the knowledge production process. Diverger attitudes may be a valid reaction to the barriers and transaction costs associated with closing the gap between sectors and disciplines, and the limited perceived benefits of doing so. Further research on this area would be valuable for understanding the role of individuals' attitudes at science policy interface. Individuals' experiences at the science-policy interface may bring to light the difficulties involved in bridging the science-policy gap at the practical level, and reasons for cynicism towards the claims of cross-sectoral and crossdisciplinary integration.

As with crossdisciplinary research, context dictates the level of outreach that is most beneficial to the project. For future research on the role of attitudes in science-policy interactions, it may be important to consider what level of experience respondents have of the science-policy interface. The survey instrument could ask, for instance, if an individual has been involved in specific kinds of research program, such as those involving multiple actors from across disciplines and science-policy fields. Other types of experience, such as working with research institutes or government departments, and collaborative work with non-academic stakeholders, may also be important drivers of science-policy attitudes and, by extension, predictors of research prioritization.

Methodologically, latent class cluster analysis was used to segment respondents according to the strength of their agreement with personal (Schwartz, 1994; Stern et al., 1998) or professional values (Lawton and Rudd, 2014). The benefit of latent class cluster analysis compared to other methods like hierarchical or k-means cluster analysis is that it is a model-based approach (Magidson and Vermunt, 2004). This offers a variety of model selection tools that give the researcher greater command over the final parsimonious model (Burnham and Anderson, 2004), where selection of the final model is informed by the research question (Scarpa and Thiene, 2005; Vermunt and Magdison, 2002). This means that context affects which method best explains variance in the data (Burnham and Anderson, 2004). To add robustness to model-selection, we carried out a number of post-hoc tests to independently verify that differences in segmentation were significant. The result was a set of three-cluster models for personal and professional values that helped to compare alternative models of agreement with converger and diverger attitudes. These results were consistent with previous suggestions (Hoppe, 2009) that converger and diverger attitudes are best conceived as ends of a spectrum rather than as a dichotomy. The ability to select models based on different information penalty terms contributed greatly to the sensitivity of subsequent researcher analysis of attitudes to the science-policy interface in the natural resource management sphere (Burnham and Anderson, 2004). However other approaches may also be available, such as Qualitative Comparative Analysis (QCA) (Rihoux et al., 2009), which may be used to identify combinations of attitudinal, value responses, and sociodeomgraphic variables that act as significant drivers on the research priorities of the same group of natural resource practitioners as studied in Chapter V (recall Fleishman et al., 2014).

Further research could also test whether converger attitudes stem from certain personality traits. Although we tested for interactions between value clusters and converger-diverger clusters in Chapter V, it may be that larger samples would demonstrate the presence of certain types of personal beliefs as drivers of converger attitudes. One possible candidate would be the desire for influence and impact, coupled with biospheric or altruistic motivations. It is commonly assumed that biospheric and egoistic values have opposing influences on environmentally sustainable behavior (see e.g., Groot and Steg, 2008).

However, the relative importance of values in explaining beliefs varies across different types of beliefs (Bilsky et al., 2011; Dietz et al., 1998). This suggests that in certain contextual situations, particularly those related to environmental issues, desire for impact and influence does not equate to concern for oneself, so much as concern for others around you, and the planet in a biospheric sense. Further research should test the effect of impact motivations on personal values, professional attitudes, especially those towards the science-policy interface, and the prioritization and utilization of evidence.

Entrepreneurs

The relationship between expert entrepreneurs, evidence credibility, and the salience of policy narratives can be seen to operate through a complex system of trade-offs at the science-policy interface. The model outlined in Chapter III contributes to existing theory on the role of policy entrepreneurs (Kingdon, 1995; Roberts and King, 1991), and recent recognition of the importance of entrepreneurial individuals in the popular and policy spheres.[11] Methodologically, Chapter III identified entrepreneurs by asking interview respondents which individuals or organizations championed each evidence source listed in the questionnaire. Responses were in open non-structured format: the elicitation method was an open question: 'which individuals or organizations did you associate with championing' each evidence source evidence source. Transcripts were coded by the lead researcher, using Internet research where necessary. These figures were then totalled and ranked, and presented as a percentage for each evidence source. The limitation of this elicitation method was that it depends on respondents having prior knowledge of the evidence report, and of the entrepreneurs active around this report. There was also the risk of respondents repeating 'common knowledge' that certain individuals were active as entrepreneurs of the report, representing second-hand information from other sources, rather than first-hand observations by interviewees. It may also exclude entrepreneurs associated with other evidence reports not included in the survey. However, the benefit of this method was that it focused recollection onto a fixed set of research and policy outputs, helping to reduce the cognitive complexity of the exercise. It also reduced the number of potential entrepreneurs to a manageable level for analysis.

The strength of this approach comes through its pairing with the Cash et al. framework (2002) of expert credibility, societal legitimacy and the successful

[11] Professor Watson, for instance, was awarded the prize for Science and Innovation in 2014, recognizing "outstanding visionaries and leaders in the fields of policy, science, entrepreneurship, and civil society". http://www.unep.org/champions/news/champions-of-the-earth-2014-winners-announced.asp#sthash.O9aKggbL.dpbs

entrepreneurship of scientific concepts for policy salience. This framework hypothesizes that falling below a threshold of credibility, salience, or legitimacy, "will trigger the rejection of information or resistance to a recommended action" (Cash et al., 2002, p. 7). Implicit in this analysis is an assumption that legitimacy leads to influence, and that this influence is increased by the boundary-spanning actions of policy actors (Gieryn, 1983; Jasanoff, 1987). Applied to the role of individuals in the science-policy process, it suggested that entrepreneurs are considered as such where they balance thresholds of expertise and relevance to broader policy issues. Expert entrepreneurs were found to bring increased salience to evidence reports like the UKNEA, TEEB, or Making Space. This allowed experts to become entrepreneurs of broader policy issues (specifically metaphors around ecosystem-based management and environmental economics). They symbolized consensus, relevance and credibility (Collins, 1992), and these attributes in turn brought legitimacy to the broader policy narrative. Their influence transcended the mere expert or communicator of scientific information (Brickman et al., 1985). Consequently, scientists' championing of scientific evidence for policy purposes was influential in maintaining thresholds of evidence salience and legitimacy.

Extending these findings to other policy systems, we can say that entrepreneurs play an important role in championing the evidence reports associated with them, as well as broader evidence-based policy narratives like ecosystem-based management, the ecosystem services framework, and natural capital valuation.

- Expert entrepreneurs like Professors Bob Watson and John Lawton brought 'transdisciplinary' attributes to bear on environmental economics and ecosystem-based management narratives, respectively. These individuals acted as experts at the top of their own discipline who were able to engage and integrate experts from a range of other disciplines, to greater and lesser degrees of disciplinary integration in the research production process (recall Chapter I). They also took on a boundary-spanning role. Professor Watson demonstrated the clearest example of this, presenting information and policy recommendations of the MEA and ecosystem service valuation in the years preceding the inception of the UKNEA. Professors Lawton and Bateman also became regular presenters and attendees at policy workshops, conferences, and working groups. In this way, they embodied transdisciplinary working by performing both expert and policy actor roles;
- Expert entrepreneurs like Professors Watson and Lawton brought 'trans-expert' attributes to bear on environmental economics and EBM narratives. Scientists describe science for the public and politics, "hoping to enlarge the material and symbolic resources of scientists" (Gieryn, 1983, p. 782). They do not merely

communicate, but translate, bestowing 'trans-scientific' authority and symbolic power on the evidence reports they champion (Brickman et al., 1985). Scientific symbols provide frames that influence people's perceptions of the world around them (Jasanoff, 2005). The expert 'symbol', whether an entrepreneurial actor or a widely cited scientific report, is powerful not only for the information it provides, but also for the authority, credibility, and legitimacy it represents to certain groups in society (Yanow, 1996);

- Once their expert credibility and entrepreneurial status is confirmed, entrepreneurs become an important symbolic resource to be used in the development of policy narratives. As well as evidence produced by entrepreneurs and accumulated over their careers, entrepreneurs become figureheads, or go-to authorities for the evidence they are seen to represent. Other groups may use their evidence for strategic purposes. However, considerable impact can be achieved by having the expert entrepreneur represent the evidence report or broader evidence-based policy narratives like EBM or the ecosystem service framework. Some, like Making Space for Nature (2010), or the Stern Review on Climate Change (2007), were independent government-sponsored reports. However, it is also common for expert entrepreneurs to be used to strategic effect as figureheads for NGO reports (e.g., the "Bird Report" commissioned by the RSPB, 2007, and the "Marmot Review", commissioned by the Institute of Health Equity 2010, both included in analysis in Chapter III);
- A wide body of literature exists on the skills required for successful boundary work between science and policy. However, there is also an element of randomness about entrepreneurship at the highest level of expertise. Although one may be able to train some of the skills required (Hoppe et al., 2013), becoming an entrepreneur may be a combination of nature, nurture, and luck. Just as evidence enjoys greater impact from being in the right place at the right time, so individuals like Professors Watson, Lawton and Bateman pursue standard academic careers until a pertinent policy issue becomes salient.

Two models of scientific policy advice have been envisaged. The 'Hail to the Chief' model sees government scientific advice coming from an eminent individual at the very top of the scientific food chain. In this model, entrepreneurial provide authority and policy salience that transcends their expert status. In this way they may be seen as scientific 'big beasts', whose influence is beneficial on the wider impact of expert reports and evidence narratives. However, there are also risks involved in being over-reliance on entrepreneurs, since the expert entrepreneur can suffer losses of credibility as well as increases in policy salience (recall Figure 1, Chapter III).

An alternative 'ecosystems of expertise' approach' focuses on the collective network of experts involved in the production, translation interconnections of expert-based knowledge for policy purposes. In this model, entrepreneurs are important bridges between expert and practitioner worlds. Entrepreneurs are one among many network intermediaries that functionally connect experts, professionals, learned societies to policy-makers and practitioners (Wilsdon and Doubleday, 2013). It is hypothesized that science-policy interfaces have greater longevity and sustainability and where 'webs of expertise' underlie the 'charismatic megafauna' of expert entrepreneurs.

Case study two: The Stern Review

The *Stern Review on the Economics of Climate Change*, henceforth *The Stern Review* (2007) was produced by a team led by Nicholas Stern at HM Treasury. It represented a paradigm shift in the narrative construction of climate change, presenting climate change as an economic externality and case of market failure. In this way it reframed the causal story as one of cost-benefit trade-offs underpinned by long time horizons, risk and uncertainty. This involved a reframing of economic solutions in terms of costs and benefits in terms of major, potentially irreversible, non-marginal change. The causal story offered by the *Stern Review* demanded urgency of response, since delay in action would lead to more and potentially irreversible climate change impacts and higher mitigation cost (Stern, 2007).

The Stern Review enjoyed considerable impact at the policy level. The report, and the entrepreneurial activity of its main author, has been attributed to the development of the Department for Energy and Climate Change (DECC) in the UK, the first government department to be directly responsible for climate change in any jurisdiction. As noted by one ex-Minister for the Environment (unreported interviews for Chapter III), "the importance of reports like TEEB and the UKNEA did for the natural environment what Stern's Report did on the economics of climate change: Both said 'there are huge economic costs to carry on as we are, and there is an economic benefit to doing things in a different way'" (Hilary Benn, research interview 2011). Its impact extended beyond the UK, with other countries commissioning their own Stern-style reviews, international organizations and NGOs like Kyoto2 taking it up as evidentiary support in their advocacy work[12], and informing the climate mitigation strategies of the UN.[13]

To recall the model of credibility and salience trade-offs (Figure 1, Chapter III), the Stern Review enjoyed rapid increases along the salience axis. However, it suffered from

[12] http://www.kyoto2.org/page49.html
[13] http://www.uneca.org/acpc/pages/economics-climate-change

open and at times vitriolic criticism from some within the academic economic community that affected its level of credibility along the vertical axis. The most notable critiques came from Nordhaus (2007; 2008), who maintained a steady discourse against Stern's choice of economic discount rates within economics journals over the course of more than five years. Discount rates are used in economics to compare economic effects occurring at different times, converting future economic impacts into their present day value. The choice of discount rate has a large effect on the result of any climate change cost analysis, with higher discount rates justifying lower investment in mitigation, but lower rates resulting in higher investment in mitigation (Metz and Davidson, 2007). The standard range of discounting for future effects is 3%. The Stern Review based its calculation of the costs and benefits of climate change on a discount rate of 1.4%. Consequently, the Stern Review was criticized for its "radical revision of the economics of climate change" (Nordhaus, 2007, p. 686). Norhaus' complaint was that Stern's evidence, the causal story it underlined, and the solutions it implied, "depend[ed] decisively on the assumption of a near-zero time discount rate combined with a specific utility function" (Nordhaus, 2007, p. 686). Yohe and Tol went further, launching a volley of scathing attacks almost unheard of in published academic writing, accusing Stern of "putting ideology ahead of analytics" (Yohe and Tol, 2008, p. 232). When Stern was accused of "shoddy analysis and questionable assumptions" (Yohe and Tol, 2008, p. 237), it was a serious academic slap in the face.

Stern responded with a defense to the basic "theories of public economics", accusing his critics of a "whole series of basic mistakes" that "grossly underestimated the scale of damages and risk" (Stern, 2010, p. 278). Stern adopted a precautionary causal story of large-scale and irreversible climate costs, which demanded precautionary action to counter his critics. The established narrative of "ridiculously small losses from business-as-usual" would encourage insufficient and "modest policy action" (Stern, 2010, p. 279).

The Stern case illustrates the tensions and inconsistencies inherent in entrepreneurial activity. Stern came up against strong counterclaims on the robustness of his evidence from experts using different economic assumptions. What contextual factors account for this difference in Stern's case?

First, the complexity, uncertainties, and long-term nature of climate economics were characteristic of a 'wicked' problem. Wicked problems are socio-ecological problems that are difficult or impossible to solve due to incomplete or contradictory knowledge, interconnections with other problems, the stakeholders involved, and the large economic burden (Sarewitz, 2004). The science around climate change fits the model of high-risk, high-uncertainty post-normal science (Funtowicz and Ravetz, 1991). In high-risk contexts, knowledge claims face heightened political scrutiny. Climate change is defined by high uncertainty in predictions of climate change and its impacts. Climate models are approximations of future climate trends, and subject to considerable variance depending on the underlying assumptions of the forecasting models (Weitzman, 2011). Consequently, the expert audience in the climate change context is acutely aware of the need to maintain credibility through transparency and use of best-practice standards agreed by the wider expert community (see e.g., IPCC, 2007; 2014).

When it came to applying discount rates outside of established bounds of economic science, the wider expert community was unwilling to accept the trade-offs in credibility represented by the *Stern Review*. The priority for the economic expert audience was to protect the credibility of economics evidence in the region of expertise, over and above any motivation for greater salience and policy impact in the region of entrepreneurship. The *Stern Review* was therefore criticized for providing "easy ammunition for those with vested interests in preserving the current fossil fuel economy" (Yohe and Tol, 2008, p. 237). Stern's divergence from the accepted norms of economics were made less justifiable when "standard economic tools applied under standard economic assumptions call for greenhouse gas emission abatement today" (Yohe and Tol, 2008, p. 237). The worst fears of this camp were realized when the Global Warming Policy Foundation used Tol's criticisms to challenge the UK governments climate mitigation policies (Lilley, 2012). Stern's choice of low discount rate also allowed climate sceptic governments, like Australia, to argue that "modestly changing" the Review's assumptions about discount rates "reduces the damage cost estimates by more than half" (Australian Greenhouse Office, 2004).

Second, expert contention arose within the economics discipline. This suggests that, in some cases, the closest neighbors may be most critical. Experts within the same discipline have greater ability to scrutinize and criticize knowledge claims. All those who have submitted their work to academic journals have felt the harsh sting of peer review by an expert versed in the technicalities of their own discipline. In contrast, interdisciplinary research brings together experts with very different specialisms. Experts from across broad disciplinary boundaries are less capable of arbitrating each other's validity claims due to lack of technical training. They may operate on trust that others are operating within the accepted norms of their discipline. Consequently, they are not in a position to critically deconstruct each other's claims.

Third, as the name suggests, the *Stern Review* was strongly associated with one individual. Partly this was a consequence of it being a civil service output, which ensured the anonymity of the majority of its authors. This had some benefits in the region of entrepreneurship over a dry government-authored report. It ensured a receptive and primed policy audience for the final document. The transdisciplinary connections and 'insider' status of the review operated as a science-policy interface in its own right. However, it also increased the perceived association with policy objectives and policy capture among the expert community. This meant that the decision to apply lower discount rates was associated with the personal judgment of one individual, rather than the outcome of agreement among the wider disciplinary community, making it less robust to critical attacks. In contrast, the UKNEA had considerable entrepreneurial support from Professor Watson, but was seen as the work of an extended research community, and *Making Space*, which was given the moniker of the '*Lawton Report'*, nevertheless maintained disciplinary consensus with the academic and NGO communities.

Following the model of credibility and salience trade-offs outlined in Chapter III, Stern's entrepreneurial capital led to higher levels of policy salience. Like Icarus, Stern's impact on policy shone brightly. But by flying close to the goal of policy salience and impact, Stern became too closely associated with the policy world. Furthermore, without the backing of the wider disciplinary community, the credibility of the *Stern Review* was undermined. The economic foundations of credibility of the *Stern Review* melted like wax under the glare of his disciplinary peers. The result was a loss of credibility, an inability to maintain disciplinary consensus, and a reduction in perceived legitimacy to the wider academic community. Stern fell from entrepreneurship and into the region of advocacy.

The Stern case illustrates the risk of over-reliance on entrepreneurs. The danger of pursuing policy impact through expert entrepreneurship is that the entrepreneurs' association with the very policy processes they are praised for influencing can lead to losses in credibility. In worst-case scenarios, the expert entrepreneur suffers a step change from the region of entrepreneurship into the region of advocacy, with resultant losses in expert, and wider audience legitimacy. The extent to which these losses translate into reductions in the level of policy impact remains to be assessed empirically.

The examples outlined in this case study demonstrate that trade-offs of credibility and salience do not operate equally in all contexts. In the case of the Stern Report, the disciplinary spats between Stern, Tol, and others did not appear to damage Stern's standing as an entrepreneur in at the popular and political realms. Stern's findings form the basis of the Global Commission on the Economy and Climate, dubbed '*Stern 2*'.[14] It continues to be referred to in the UN's climate strategies.[15] It seems, therefore, that expert disagreements between Stern and the wider economic community on basic assumptions of discount rate economics have not damaged the legitimacy and standing of the *Stern Review* in the policy

14 http://www.ft.com/cms/s/0/cf2f2f6c-2489-11e3-a8f7-00144feab7de.html#axzz3PNajk3X6

15 http://www.uneca.org/acpc/pages/economics-climate-change

and popular realms (perhaps because the arguments were too intricate for a popular audience). Nevertheless, reductions in Stern's credibility have provided ammunition for climate sceptics who use Stern's loss of expert legitimacy to cast doubt on the causal story of economic cost-benefits of early mitigation on climate change (notably Australia, Canada, and the USA).

Coalitions and dichotomous beliefs

The explanatory power of the Advocacy Coalition Framework (ACF) (Sabatier and Jenkins-Smith, 1993, 1999) was tested in Chapter II with reference to the public consultation process around the Natural Environment White Paper. Consultation documents were coded with labels reflecting the deep, policy core, or secondary-instrumental motivations of the author organizations. A number of innovations were attempted in the presentation of quantitative data captured through qualitative coding. After analyzing policy documents and consultation responses for the emergent themes they contained, I combined quantitative coding outputs from the qualitative data within the theoretical framework of the Advocacy Coalition Framework (ACF). This inductive approach (Creswell, 2013), divided coding themes by deep, policy and secondary belief levels for each coalition based on ideological closeness with pre-coding deep core issues, centrality to the substantive policy issue, and implementation practicalities (Sabatier and Jenkins-Smith, 1999). Shared coding was taken as an indication of belief alignment, positing that higher numbers of shared belief issues for each coalition represented stronger coalition alignment.

This provided a number of novel presentational forms for the data. For instance, magnitude of coding observations could be visualized by circle diameter (Figure 2, Chapter II) to give a sense of the relative weight of importance attached to each coding theme across the sample. These representations were given as a proportion of the total number of codes. Coding themes shared between groups were presented as a Venn diagram representing overlapping coalition beliefs that was also area proportional to coding observation magnitude (Figure 3, Chapter II). This provided an intuitive representation of overlapping beliefs held between coalitions, employing a central theoretical assumption of the ACF. There is a risk that those who provide most feedback in survey open-end response will have most influence on the analysis – a 'dominating effect' where whoever shouts loudest makes their will known. I corrected for this by quantifying themes only once per question: a respondent who raised the issue of natural capital valuation twelve times in answer to one question would not exert any more influence on analysis than someone who raised it only once. However, respondents with 'pet issues' that they raised throughout the survey and across multiple questions would succeed in raising the profile of this issue in the analysis. The alternative would be to allow only one theme to be coded per respondent per survey. However, this would have an effect on the quantification process, since we would have no idea if that issue had been raised in passing, or as a key issue to our respondents.

Chapter III analyzed interview responses grounded by two interpretative policy frameworks, the Narrative Policy Framework (Jones and McBeth, 2010; Shanahan et al., 2011) and Stone's (2002) interpretative policy analysis approach of metaphors and narrative strategies. This provided the structure for coding and subsequent quantitative analysis. While this may have influenced the content of the coding, our grounding in each theoretical framework was made clear throughout that interpretation and analysis. This method could be improved in the future with inter-coder reliability testing (Kolbe and Burnett, 1991).

Comparison of methods across Chapters II and III highlights the strengths and limitations of the ACF for assessment of contextual evidence impact.

- **Lesson 1: Where analysis takes the form of interview responses or surveys with individuals, it is inadequate to construct coalitions based around organizational background or professional affiliation because individuals hold different personal and professional values.** For example, although research interviews for Chapter III explicitly invited respondents to express their personal, rather than professional opinions, and assured anonymity of responses, this study highlighted some of the limitations of the ACF approach. A common question from those interviewed was: "do you want me to answer from my organization's perspective, or my own?" Individuals may be wary of expressing their personal opinions on professional matters, or find it difficult to separate their professional from their personal attitudes (Harvey, 2005). Grouping responses according to their host organizations falsely assumes that their values and beliefs represent the views of all those in the organization. Values and beliefs identified through coding of consultation responses (as in Chapter II) are more reliable sources of organizational values, drafted, approved and published by a number of individuals employed by each organization, and do not represent the personal values and beliefs of the individuals working for them.
- **Lesson 2: application of the ACF can lead to a polarizing heuristic whereby two coalitions are constructed based on opposing deep core beliefs.** Central to the ACF theory is the assumption of immovable deep core beliefs (see Sotirov and Memmler, 2012 for a recent metareview of ACF studies in the natural resource policy area). This implies a potentially pessimistic view of evidence utilization to escalate the distance between coalitions producing a 'devil shift', whereby coalitions

exaggerate the negative features of their opponents' narratives, to damage the credibility of another group's arguments (Shanahan et al., 2011). This occurs most notably in policy areas characterized by 'wicked' or intractable problems (e.g., climate change, Sarewitz, 2004).

Quantitative coding methods: Recommendations for Government analysis of consultation responses

The explanatory power of the Advocacy Coalition Framework (ACF) (Sabatier and Jenkins-Smith, 1993, 1999) was demonstrated in Chapter II with reference to the public consultation process around the White Paper (Lawton and Rudd, 2013). Quantification of coding for content analysis and interview responses around the Natural Environment White Paper provided valuable quantitative data for analysis of shared beliefs, and captured through the iterative coding of themes of interest.

There is potential to increase the transparency of government consultation processes by applying quantification techniques to the analysis of consultation responses. Currently, outputs from consultation processes involve ad-hoc government summaries of the findings of consultation responses. This process assumes that government reporting faithfully reflects the themes and issues raised by stakeholders from a range of different interest groups and professional affiliations. The process is open to intentional and unintentional bias:

- Presentation of important issues may be skewed by the government's own research questions and expectations for policy outcomes (confirmation bias, i.e., giving more credence to consultation evidence that accords with prior visions of policy);
- Arguments made strongly by a minority of respondents of similar backgrounds may attain greater importance in the report (clustering illusion);
- Those analyzing consultation responses may unwittingly give more credence to the responses of some groups over others (implicit bias).

The methods for measuring, quantifying, and reporting content coding explored in this thesis could improve the government analysis of consultation responses. They would allow government consultations to:

- Show clearly and transparently the full range of issues raised in the consultation;
- Report the number of times (magnitude) that each issue was raised. With careful sensitivity measures, this metric could be used as a proxy for issue importance;
- Attribute coding to each respondent organization. This would increase the transparency of the consultation summary process, and highlight where pet-issues

are lobbied by certain groups. It may also help identify coalitions who share policy objectives and core underlying assumptions;

- The quantification of consultation responses would lead to greater credibility and reliability in the presentation of key issues identified from the consultation process;
- It would no longer be possible to marginalize certain issues, since the number of times they were raised would be visible to the public.

There is still work to be done on the methodology of coding quantification. I acknowledge the risk of quantification of coding based on raw observation data:

- The approach can lead to situations where the repetition of a particular theme or agenda by a single organization could drown out equally important, but less-repetitive presentations from other organizations;
- The importance of an issue may not be reflected in the number of times a theme is mentioned (e.g., consultees may order their points in order of priority);
- Respondents from multiple organizations with similar core beliefs and policy objectives may collude to raise the number of observations for pet issues.

However, even within this thesis, subsequent applications of the quantitative coding method have introduced measures for greater sensitivity, such as proportional coding of themes relative to total coding for that source, or binary coding, where only one observation is recorded per theme within a set measure (sentence/paragraph/section/whole text; see e.g., Chapter III). I welcome future methodological research to increase the robustness of the quantification of thematic coding.

The Narrative Policy Framework

The Narrative Policy Framework (NPF) takes the ACF as its theoretical starting point, following many of its underlying assumptions about individual learning and the causal explanatory power of coalitions (Jones and McBeth, 2010; Shanahan et al., 2011). The NPF seeks to capture policy beliefs as a measure of coalition strength, and to find statistically significant differences between coalitions core beliefs. More helpfully for the analysis in this paper, the NPF also provides a framework for capturing the effect of narrative discourse on policy change at the micro-, meso-, and macro-level.

- Micro-level narrative strategies include the "how, when and why policy narrative shape public policy processes, designs and outcomes" (McBeth et al., 2014, p. 237). In this case, they constitute the direct strategies that improve the communication, translation and utilization of technical evidence into a format that is salient to non-expert actors. These include practical presentation and linguistic techniques that convert technical information into communicable plain English concepts, such as those commonly identified by research impact assessments (e.g. Clark, 2007; Nutley, 2007).

- Meso-level analysis tracks policy narrative persuasion through the "examination of strategic construction and communication of policy narratives by coalitions to achieve a desired policy goal" (McBeth et al., 2014, p. 237). This level of analysis identifies the construction of causal stories (links constructed from a problem's cause to a wider societal effect, in a way that bestows authority on groups offering certain solutions), scaling up (associating policy issue to problems of greater perceived societal weight), and policy metaphors (comparisons between narratives founded on particular values and judgments; see Stone, 2002).
- At the macro-level are overarching metanarratives that encompass an underlying viewpoint of the world (e.g., consumerism, environmentalism, traditionalism etc., see Mcbeth and Shanahan, 2004). In this case, metanarratives may include deep core beliefs around the power of marginal economics and or ecological conservation as a dominant worldview for ordering society, political solutions, and our understanding of the world 'out there' (see e.g., Lawton and Rudd, 2013b). For instance, two broad meta-narratives emerged from our analysis, that appeared to frame respondents' understanding of ecosystem knowledge around *ecosystem-based management (EBM)*, defined as the predominantly ecological ways in which environmental problems were framed, and those based around *environmental economics* approaches of ecosystem services, stocks, and flows. These narratives were based on underlying ecological and economic evidence. However, they were also 'trans-scientific', building on the evidence base, but developing their own policy narrative frames that were used in strategic negotiation of public policy. Furthermore, by linking EBM and environmental economics metaphors to the institutional arrangements that came out of the White Paper, it again raised the question of how sustainable any partnership of approaches, in this case a *hybrid regime* of knowledge coproduction, could be in the medium to long-term (linking to the policy partnership framework from Chapter II).

Case study three: Ecosystem policy narratives

Taking together the findings from Chapters II and III suggests an increasing trend towards ecosystem service valuation in UK environmental management and policy. This can be seen in the influence attributed to the UKNEA by policy actors, the dominant ecosystem service wording of the Natural Environment White Paper (2010), and the discourse accompanying White Paper implementation measures like Local Nature Partnerships an Nature Improvement Areas. These policy outcomes were strongly framed by environmental economics metanarratives. Using the system/economic orientation grid developed in Chapter II (recall Figure 5) we originally predicted that the trend in ecosystem service discourse in the UK would be accompanied by increased monetization of ecosystem stocks and services and a parallel focus on natural capital within GDP-equivalent stock-taking of environmental resource (such as that carried out by the Natural Capital Committee, 2014).

The problem with this interpretation is that it suggests that environmental economics and EBM approaches to environmental management are opposed and adversarial. However, an alternative perspective would highlight their complimentary aspects, which may be well-suited to sustainable policy partnerships. Environmental economics narratives provide important explanatory power which have been successfully applied to environmental externalities such as anthropogenic pollution (Coase, 1960), natural resource use and sustainability science (Brundtland Report, United Nations, 1987), and climate change (Stern, 2007). Environmental economics provides important insights to environmental management that complement and expand EBM policy solutions. Environmental economics narratives help to quantify (not necessarily monetize)[16], the flow of ecosystem benefits (Barbier et al., 2009). This helps to focus management solutions onto priority area, not just for human benefit (in provisioning and some regulating services), but in theory to the benefit of natural systems themselves (supporting and regulating services) (Balvanera et al., 2006).

Policy outcomes are dependent on the interpretation of knowledge by policy makers and the strategic objectives to which hybrid EBM-environmental economics narrative are put. This leads to the question of what other ways of valuing ecosystems are possible. What, we may ask, would a pure EBM approach look like? In practice, there may be no such thing. The sustainability of the hybrid regime depends on compromise and joint work between stakeholders with different core beliefs and motivations. These present different contexts, and relative pros and cons of EBM and environmental economics metanarratives. Policy outcomes are produced through coproduction of a hybrid regime consisting of

[16] It is important to stress that ecosystem service solutions do not necessarily imply economic governance paradigms (Balvanera et al., 2006; Farber et al., 2002). The ecosystem services framework merely entails the quantification of ecosystem stocks and flows. The choice of *numeraire* is commonly monetary, but this is, at its simplest level, a practical consideration, making use of a metric that the broadest selection of stakeholders are familiar with (Balvanera et al., 2006; Boyd and Banzhaf, 2007). As noted by Lord Deben, ex-Minister for the Environnent, "the point about money is that it is an index of value…To value the worth of things, that's when you start to get benchmarks which you can use to compare" (Lord Deben, unreported interview for Chapter III).

elements of both: A new environmental metanarrative of ecosystem serviced optimization and integrated partnership approaches to improving and connecting ecosystem elements of the natural world.

Future research directions and policy recommendations

This thesis explored a range of methods for assessing contextual research impact within a number of environmental science-policy case studies. The work contained within this thesis aimed to contribute to the wide and detailed literature on research utilization and impact. Much work has been done in this area. Authors like Nutley (2007) and Clark (2007) produced comprehensive reports outlining techniques and approaches to improve research production and communication for policy and practitioner audiences. Van Den Hove (2007) and the SPIRAL team (van Kerkhoff and Lebel, 2006; Young et al., 2014; Young and Watt, 2013) have done impressive work looking at the interpersonal and institutional processes involved in the transfer of science to policy.[17]

Larigauderie and Mooney (2010) note that in order to be successful, the science-policy interface for biodiversity and ecosystem services at the international level needs four complementary components: research; observations; assessment; and policy. Implicit in this pronouncement is a strong weighting towards credible scientific evidence. Research and observations must be robust to the scrutiny of academic peers and the wider societal decision-making community. Uncertainty should be acknowledged and communicated (in line with post-normal scientific approaches to high-risk, high-uncertainty knowledge areas, Funtowicz and Ravetz, 1993). In urgent and high risk policy areas, disagreements between experts may increase the nuance and credibility of scientific evidence, but also reduce the impression of consensus, thus reducing the salience and impact of this information. Clear communication, simple language, lay concepts, and the presentation of expert consensus increase the salience of evidence. However, these strategies may also lead to accusations of policy capture, with losses of legitimacy as a result (Jasanoff and Wynne, 1998). One way to reduce the perception that salient evidence has been captured by policy is to understand more clearly the strategic nature of evidence use in the policy process. The insights of discursive and narrative frameworks of the policy process recognize the necessary part that narrative construction plays in the dissemination and utilization of evidence (McBeth et al., 2014; Yanow, 1996).

[17] This work has been addressed explicitly through institutional analysis paper developed during my summer at the Thor Heyedaal school (not included in this thesis; see Cent et al., 2011).

Research impact is increasingly important in science-policy discourse, becoming an integral part of research council mission statements (ESRC, 2009; NERC, 2011; RELU, 2010). There is a risk that impact narratives could lead to an impulse that all research should have wider impact on society. Exclusive focus on extended societal impact may crowd out 'blue sky' research. Science that always has one eye on direct or wider policy impacts may follow narrower research questions than research addressing foundational questions of understanding (Kilduff et al., 2011). It is important that ecological science continues to produce foundational research, and that it is not seen to be unduly influenced by the interests of short-term policy impact (Locock and Boaz, 2004). As outlined in the credibility/salience model, increases in salience can lead to reductions in credibility (recall Figure 1, Chapter III). At the most basic level, expert status has symbolic need for a body of evidence that can claim independence and objectivity (Fisher, 1990). The discoveries that will be used in the next round of policy debates – that form the basis of future synthesis reports and policy narratives – will come from the current generation of foundational research. Scientific credibility may, in the long-term, be more important than policy salience. Thus, while societal needs and values continue to have a place in the prioritization of research, it should not always follow that researchers need to defend their work through demonstrable societal impact in the short- to medium-term.

Second, there is the risk that the search for broader societal impact, such as that outlined by the REF process in English universities (REF, 2011), will culminate in shallow box-ticking definitions of wider impact. Researchers trained in social media and reporting of results to non-academic audiences may nonetheless fail to engage in substantive convergent behavior across disciplinary boundaries and professional sectors (Owens, 2013). Departments may find it easier to groom a select number of 'superstar' researchers engaged in high-end political working groups or national media outlets, while the remainder continue to work in their disciplinary silos (Campbell, 2005). To some extent this is a valid trade-off, since the entrepreneurial 'big beast' is so rare a creature. However, it also masks the need for procedural and institutional changes to overcome the barriers that still prevent transdisciplinary research (Jacobs and Amos, 2010).

Context is key, and there is a time and a place for blue-sky research as much as there is strategic policy impact. Synthesis reports and evidence entrepreneurs work to successfully communicate research for strategic purposes, but they rely on ecosystems of robust and credible evidence that underwrite their activities. Improving our understanding of the trade-offs between credibility and salience will help both in the production of quality research, and its utilization in societal decisions. To this end, we should seek the tools that help us to understand how contextual factors influence the utilization of evidence. This requires comparison, both of the methods and the findings of case studies across numerous problem areas, environmental and other, and various jurisdictions. Further work is required to build these together with further empirical study, with the ultimate aim to produce a generalized framework. That aim may be ambitious, but I believe it is an important addition to existing research utilization and science-policy literature. I present this thesis as a first foray into this exciting area of evidence impact assessment.

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Appendices

Chapter III

S1, Chapter III - Entrepreneurs by evidence report – full list of reports

Chapter V

S1, Chapter V – Survey instrument

S2, Chapter V - Professional and demographic attributes of respondents to this survey and to the survey implemented by Rudd and Fleishman (2014) and results of χ^2 tests of whether attributes differed significantly between the two samples.

S3, Chapter V – Latent class model diagnostics: personal values

S4, Chapter V – Latent class model diagnostics: professional values

S1, Chapter III - Entrepreneurs by evidence report – full list of reports

	Bird Natural Thinking	Financing Nature	Foresight Future Food & Farming	Foresight International Climate Change	Kremen Pollination	Making Space for Nature	Marmot	NCI Valuing Our Life Support Systems	Securing a healthy natural environment	Silent Summer	State of Natural Environment	TEEB	ThinkBIG	WWF Living Planet	UK Biodiversity Indicators	UKNEA	Values of Volunteering	Total (*n*)	Total %	Total Rank
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*			
Central Government	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	6	0	9	6.8	9
Defra	0	0	0	0	0	5	0	0	1	0	0	3	0	0	1	2	0	12	9.0	7
ENGOs	0	3	0	0	0	10	0	0	0	1	0	0	1	0	0	5	0	20	15.0	2
Environment Agency	0	0	1	0	0	8	0	0	0	0	1	1	1	0	0	2	0	14	10.5	4
Landowners	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1.5	10
Pavan Sukhdev	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	13	9.8	5
Professor Bob Watson	0	0	2	0	0	1	0	0	0	0	0	1	0	0	0	22	0	26	19.5	1
Professor Ian Bateman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	7.5	8
Professor John Lawton	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	15	11.3	3
Research Councils	1	0	1	0	0	2	0	0	0	0	0	0	0	0	0	9	0	13	9.8	5
Total	1	3	5	0	0	44	0	0	1	1	1	18	2	0	0	57	0			

S1, Chapter V – Survey instrument

1.1 In which sector or with what type of organization are you primarily employed or engaged?

- Academia (faculty, research associate, postdoctoral fellow)
- Environmental nongovernmental organization
- Government (policy-oriented)
- Government (science-oriented)
- Private sector
- Other (please specify)

1.2 What type of government organization do you work for?

- Federal government
- State government
- Municipal or city government
- Other (please specify)

1.3 Which federal department or agency you work for?

- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Energy
- Department of the Interior
- Environmental Protection Agency
- Other (please specify)

1.4 In which state or territory do you reside?

1.5 What is your age group?

- < 30 years
- 30-39 years
- 40-49 years
- 50-59 years
- 60-69 years
- >70 years

1.6 What is your gender?

1.7 What is the highest level of education that you have obtained?

- High school diploma
- Degree

- Masters
- PhD
- Postdoctorate

1.8 What was your disciplinary training?

- Agricultural and Biological Sciences
- Education
- Engineering and the Applied Sciences
- Fine and Applied Arts
- Health Professions and Occupations
- Humanities
- Mathematics and the Physical Sciences
- Economics
- Political Science
- Other Social Science

1.9 How many years have you worked in resource management or similar fields?

- 2 years or less
- 3 to 5 years
- 6 to 10 years
- 11 to 15 years
- 16 to 20 years
- 21 to 30 years
- 31 years or more
- n/a

Part 2. Personal values

2.1 Please tell us if you are **opposed** to any of the following statements as guiding principles in your life.

2.2 Now, for those values to which you are not opposed, please tell us how important they are as a guiding principle in your life. We use a **7-point scale,** where **7** means it is **supremely important** in your life, and **1** means it is **not at all important**.

Please give your first and most instinctive answer for each. Please provide a response for all statements.

- Protecting the environment, preserving nature
- Unity with nature, fitting into nature
- Respecting the earth, harmony with other species

- World at peace, free of war and conflict
- Social justice, correcting justice, care for the weak
- Equality, equal opportunity for all
- Honoring parents and elders, showing respect
- Family security, safety for loved ones
- Self-discipline, self-restraint, resistance to temptation
- Authority, right to lead or command
- Influential, having an impact on people and events
- Wealth, material possession, money
- Varied life filled with challenge, novelty and change
- An exciting life, stimulating experiences
- Curious, interested in everything, exploring

Part 3. Professional values

3.1 Please indicate whether you agree or disagree with the following **statements on evidence use in policy making** (see Hoppe, 2011). Please provide a response in each space. **5** means you **strongly agree**, **1** means you **strongly disagree**, and **NA** means you have **no opinion** on the matter.

- Worthwhile policy ideas emerge from science, but scientists have no responsibility for disseminating the policy implications of their research among policy-advising bureaucrats and politicians.
- No matter their differences, science and politics eventually serve a similar function: creating conditions for cooperation between people.
- It is admirable that scientists translate vague political ideas into transparent models, and objectify them into measurable indicators.
- In my field, one scientific discipline dominates; when researchers or advisers from other disciplines come up with different recommendations, most of the time they hit a brick wall.
- It is only natural for bureaucrats to collaborate with scientists; after all, research is a link in the chain of policy implementation.
- Uncertainty reduction through the use of science or expertise is hardly possible; learning is a matter of trial-and-error in practice.
- In public policy, learning is limited to instrumental, financial and organizational matters.
- Dealing with uncertainty primarily is a matter of thorough and honest political debate.

- Most of the time it is concepts, models or story lines originating in science that are the glue in agreement on policy development issues.

3.2 You indicated that you **strongly agreed** with the following statements about evidence use in natural resource policy and management

Please add your own comments on **why you strongly agree with these statements**.

S2, Chapter V – Professional and demographic attributes of respondents to this survey and to the survey implemented by Rudd and Fleishman (2014) and results of x^2 tests of whether attributes differed significantly between the two samples.

Variable	This survey		Rudd and Fleishman survey	
	n	%	n	%
Gender (1, n=728)=0.82, *p*=0.37				
Female	48	38.1	204	33.9
Male	78	61.9	398	66.1
Age x^2(5, n=728)=9.09, *p*=0.11				
< 30 years	5	4.0	29	4.8
30-39 years	19	15.1	104	17.3
40-49 years	32	25.4	139	23.1
50-59 years	38	30.2	193	32.1
60-69 years	20	15.9	115	19.1
≥ 70 years	12	9.5	22	3.7
Highest level of education x^2(3, n=728)=11.18, *p*=0.01				
High school or bachelor's degree	5	4.0	86	14.4
Master's degree	50	39.7	199	33.2
PhD or postdoctoral	71	56.3	314	52.4
Years of experience in resource management x^2(7, n=728)=4.04, *p*=0.78				
2 years or less	2	1.6	25	4.2
3 to 5 years	10	7.9	42	7.0
6 to 10 years	14	11.1	59	9.8
11 to 15 years	13	10.3	75	12.5
16 to 20 years	18	14.3	84	14.0
21 to 30 years	39	31.0	160	26.6
31 years or more	29	23.0	146	24.3
not applicable	1	0.80	11	1.8
x^2(5, n=728)=2.16, *p*=0.83				
Academia (faculty, research associate, postdoctoral fellow)	50	39.7	228	34.1
Environmental nongovernmental organization	11	8.7	60	9.0
Government (policy-oriented)	19	15.1	79	13.2
Government (science-oriented)	34	27.0	186	31.4
Private sector	4	3.2	21	3.1
Other	8	6.3	25	3.7
Discipline x^2(10, *n*=330)=6.90, *p*=0.001				

Agricultural and biological sciences	83	65.9	105	50.2
Education	1	0.80	7	3.3
Engineering and the applied sciences	9	7.1	14	6.7
Fine and applied arts	0	0	0	0.0
Health professions and occupations	2	1.6	2	1.0
Humanities	2	1.6	5	2.4
Mathematics and the physical sciences	10	7.9	20	9.6
Economics	3	NA	NA	NA
Political science	15	NA	NA	NA
Other social science	20	15.0	56	26.8
Science and Policy x^2 (2, n=728)=0.40, p=0.82				
Scientist (employed by academia or government)	84	66.7	414	69.2
Policy-maker (government-employed)	19	15.1	79	13.2
Other (employed by a nongovernmental organization, the private sector, or a sector not represented above)	23	18.3	105	17.6

S3, Chapter V – Latent class model diagnostics: personal values

Model[i]	Number of latent classes	Deleted statement[ii]	-2LL[iii]	AIC (LL)	ΔAIC[iv]	Number of parameters	degrees of freedom	Classification error	Entropy R2[v]
1	1	-	5565.8	5735.8	-	85	37	0.00	-
2	2	-	5356.6	5558.6	-	101	21	0.04	0.84
3 Model chosen on the basis of AIC - Loss of df	3	-	5283.0	5517.0	-	117	5	0.05	0.87
3b Simplify model by eliminating variables with highest number of significant bivariate residuals (Pearson's x^2)	3	S9 (p=0.20)	4848.6	5064.6	-	108	14	0.05	0.87
3c Drop variable (3 BVRs)	3	S14 (3 BVRs)	4478.7	4678.7	-	100	22	0.06	0.85
3d Drop variable (3 BVRs)	3	S4 (3 BVRs)	4122.3	4304.3	-	91	31	0.05	0.85
3e Drop variable (2 BVRs)	3	S6 (2 BVRs)	3785.1	3953.1	-	84	38	0.08	0.81
3f Drop variable (1 BVR)	3	S3 (1 BVR)	3510.2	3662.2	-	76	46	0.08	0.79
3g Drop variable (3 BVRs)	3	S7 (3 BVRs)	3124.1	3262.1	-	69	53	0.08	0.80
3h Drop variable (1BVR)	3	S15 (1BVR)	2810.2	2936.2	-	63	59	0.09	0.79
4 Run with reduced indicator set	1	-	2924.3	3014.3	78.1	45	77	0.00	-
5	2	-	2862.7	2970.7	34.5	54	68	0.08	0.71
6 Model chosen (minimum AIC)	3	-	2810.2	2936.2	0.0	63	59	0.09	0.79

7	4	-	2793.3	2937.3	1.1	72	50	0.12	0.82
6b Drop insignificant variable	3	S8 (p=0.22)	2488.1	2600.1	-	56	66	0.09	0.78
6c Drop insignificant variable	3	S12 (p=0.18)	2174.2	2270.2	-	48	74	0.12	0.71
8 Run with reduced indicator set	1		2259.6	2327.6	59.7	34	88	0.00	-
9	2		2202.5	2284.5	16.6	41	81	0.10	0.67
10 (Final model: ΔAIC<3)	3		2174.2	2270.2	2.3	48	74	0.12	0.71
11 (Min AIC)	4		2157.9	2267.9	0.0	55	67	0.15	0.72
12	5		2145.7	2269.7	1.8	62	60	0.16	0.72

[i] Latent-class cluster analysis produces a model for each number of classes that may be represented in the data

[ii] We sequentially deleted statements from the latent-class cluster analysis until no bivariate residual coefficients were significant at the 5% level. With each iteration we deleted the statement with the maximum *p* or the highest occurrence of bivariate residuals.

[iii] Twice the negative log-likelihood value

[iv] Akaike's Information Criterion difference value

[v] Estimate of model fit on a scale from 0 (no fit) to 1 (perfect fit)

S4, Chapter V – Latent class model diagnostics: professional values

Model[i]	Number of latent classes	Deleted statement[ii]	-2LL[iii]	AIC (LL)	ΔAIC[iv]	Number of parameters	degrees of freedom	Classification error	Entropy R2[v]
1	1	-	3253.2	3325.2	10.4	36	90	0.00	-
2 (ΔAIC≤2))	2	-	3224.8	3316.8	2	46	80	0.12	0.59
3 (AIC min)	3	-	3202.8	3314.8	0	56	70	0.15	0.65
4	4	-	3184.0	3315.9	1.1	66	60	0.13	0.77
5	5	-	3162.6	3314.6	-0.2	76	50	0.12	0.73
6	6	-	3139.8	3311.8	-3	86	40	0.17	0.74
7	7	-	3120.0	3312.0	-2.8	96	30	0.14	0.79
8	8	-	3101.0	3313.0	-1.8	106	20	0.13	0.78
2 Model chosen (ΔAIC≤2))	2	-	3224.8	3316.8	2	46	80	0.12	0.59
2b Simplify model by eliminating variables with highest number of significant bivariate residuals (Pearson's x^2)	2	S4 (p=0.90)	2872.6	2954.6	-	41	85	0.12	0.58
2c Drop insignificant variable	2	S6 (p=0.78)	2536.0	2607.9	-	36	90	0.13	0.54
2d Drop insignificant variable	2	S8 (p=0.51)	2142.6	2204.6	-	31	95	0.13	0.52
2e Drop insignificant variable	2	S7 (p=0.19)	1766.4	1818.3	-	26	100	0.12	0.51
2f Drop insignificant variable	2	S1 (p=0.25)	1491.2	1533.1	-	21	10	0.13	0.54
9 Run with reduced indicator set	1	-	1516.4	1548.4	15.3	16	110	0.00	-

10 (AIC min)	2	-	1491.2	1533.1	0	21	105	0.13	0.54
11 (Final model: ∆AIC<3)	3	-	1482.8	1534.7	1.6	26	100	0.14	0.65
12	4	-	1472	1533.9	0.8	31	95	0.12	0.68
13	5	-	1469.4	1541.5	8.4	36	90	0.17	0.70

[i] Latent-class cluster analysis produces a model for each number of classes that may be represented in the data
[ii] We sequentially deleted statements from the latent-class cluster analysis until no bivariate residual coefficients were significant at the 5% level. With each iteration we deleted the statement with the maximum *p* or the highest occurrence of bivariate residuals.
[iii] Twice the negative log-likelihood value
[iv] Akaike's Information Criterion difference value
[v] Estimate of model fit on a scale from 0 (no fit) to 1 (perfect fit)

Definitions and abbreviations

ACF: Advocacy Coalition Framework:

AIC: Akaike's Information Criterion

ANOVA: Analysis of variance

CBD: Convention on Biological Diversity

CLA: Country Land and Business Association

COP: Conference of the Parties

CSA: Chief Scientific Advisor

CV: Curriculum Vitae

Defra: Department for Environment, Food, and Rural Affairs

EA: Environment Agency

EBM: Ecosystem-based management

EIA: Environmental Impact Assessment

ES: Ecosystem services

ESA: Endangered Species Act

ESRC: Economics and Social Research Council

EU: European Union

GSSI : General Social Science and Interdisciplinary

H.M.: Her Majesty's

IEA: Integrated Environmental Assessment

IPA: Interpretative Policy Analysis

LNP: Local Nature Partnership

MEA: Millennium Ecosystem Assessment

MP: Member of Parliament

MSF: Multiple Streams Framework

NCC: Natural Capital Committee

NE: Natural England

NERC: Natural Environment Research Council

NEWP: Natural Environment White Paper

NFU: National Farmers Union

NGO: Non-government organizations

NIA: Nature Improvement Area

NPF: Narrative Policy Framework

NPM: New Public Management

ONS: Office of National Statistics

RSPB: Royal Society for the Portection of Birds

SPI: Science Policy Interface

STS: Science Technology Studies

TEEB: The Economics of Ecosystems and Biodiversity

TEV: Total economic value

UKNEA: UK National Ecosystem Assessment

UN: United Nations

VBN: Value Belief Norm

Glossary of terms

Adversarial policy system: Policy subsystems characterized by competitive coalitions marked by polarized beliefs and minimal cross-coalition coordination, fragmented authority among governments or government agencies that are aligned with one of the competitive coalitions, extensive venue shopping where coalitions seek an upper hand over rivals in any amiable venue, and policy designs with clear winners and losers and little compromise

Agora: A central spot in ancient Greek city-states. The literal meaning of the word is "gathering place" or "assembly". The agora was the center of intellectual, artistic, spiritual and political life of the city

Altruism: Disinterested and selfless concern for the well-being of others

Antecedents: A thing that existed before or logically precedes another

Anthropogenic: Caused or influenced by humans

Archetypes: Original pattern or model from which all things of the same kind are copied or on which they are based; a model or first form; prototype

Behavioral economics: A method of economic analysis that applies psychological insights into human behavior to explain economic decision-making

Belief/value scale: Psychological inventories used to determine the values that people endorse in their lives. They facilitate the understanding of both work and general values that individuals uphold

Benefit transfer: Economic method used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. For example, values for recreational fishing in a particular state may be estimated by applying measures of recreational fishing values from a study conducted in another state.

Bibliometric analysis: Methods to quantitatively analyze academic literature. Citation analysis and content analysis are commonly used bibliometric methods

Biodiversity, or biological diversity: Variety of life, including variation among genes, species and functional traits. Measured as richness (number of unique life forms); evenness (equitability among life forms); or heterogeneity (dissimilarity among life

Biospheric values: Personal moral norms about the beneficial treatment of nonhuman objects; value orientation in which people judge phenomena on the basis of costs or benefits to ecosystems or the biosphere

Boundary object: Refers to the tools that actors use, e.g. computer models, concepts or measuring standards, for knowledge production in a policy setting

Boundary person/people: refers to networks of scientists and policymakers that are formed or individual people who through their position or actions mark a boundary between science and policy

Boundary text: Refers to the way actors distinguish between science and policy in spoken and written text and define respective roles

Boundary work/workers: The process by which scientists define their roles, coordinate research, and describe science for the public and its political authorities; involves the demarcation of actions or groups by defining distinguishing characteristics and prescribing proper ways of behaviour for science and policy, and a co-ordination side defining how the two relate to each other by defining proper mutual conditions of exchange

Case study approach: A method of research used especially in sociology by which accumulated case histories are analyzed with a view toward formulating general principles

Causal story: Strategic narrative technique that links a problem's cause to a wider effect that bestows greater authority on groups offering certain solutions. They assume certain similarities between situations, and imply prescription and judgments about the correct interpretation of knowledge

Central government agencies: A permanent or semi-permanent organization in the machinery of government that is responsible for the oversight and administration of specific functions. A government agency is normally distinct both from a department or ministry, and other types of public body established by government. The functions of an agency are normally executive in character, since different types of are most often constituted in an advisory role

Central government: the executive branch of government of a nation-state

Code (also qualitative coding): An analytical process in which data, in both quantitative form (such as questionnaires results) or qualitative (such as interview transcripts) are categorised to facilitate analysis

Cognitive leadership: Conceptual direction over research project management

Collaborative policy system: Policy subsystems characterized by cooperative coalitions with some level of belief convergence and cross-coalition coordination, shared access to decision-making authority, the existence and use of consensus-based institutions, and policy designs that emphasize win-win and voluntary solutions

Commodification: Transformation of goods and services, as well as ideas or other entities that normally may not be considered goods, into a commodity

Complexity: Refers to the degree to which components engage in organized structured interactions. High complexity is achieved in systems that exhibit a mixture of order and disorder (randomness and regularity) and that have a high capacity to generate emergent phenomena

Compositional analysis: Breaking down a research report or project into individual components; the components can be present at a single point in time or over a given time span

Conceptual hooks: Ideas that are framed in such as way as to catch the attention of its audience and stick in their memory

Conceptual impact: Also known as diffuse impact, contributing to the understanding of these and related issues, reframing debates. Research that contributes to the enlightenment effect of gradual accumulation of ideas and concepts over time, providing a 'reservoir' of information into which the user community can dip

Conservation science: The interdisciplinary study of protection of biodiversity

Context-dependent: Stemming from formal language theory, refers to a statement of meaning that relies upon a situation, background, or environment for proper interpretation

Contextual impact: The fate of knowledge which is dependent on receptive and non-receptive contexts as well as the relationship between content of research, context and knowledge production processes

Converger: Attitude towards the relationship of science with policy that observes no gap between research and policy. Convergers emphasize the fluid boundaries between research and policy communities, envisaging policy-makers involved from the earliest stages of research design and experts occupying decision-making positions

Coproduction: Social processes of negotiation and deliberation that combine scientific knowledge with normative beliefs, and expertise with policy-maker judgment. Interactions between research and policy are complex and multi-directional, involving a range of social and cultural factors

Covariate: A secondary variable that can affect the relationship between the dependent variable and other independent variables of primary interest

Credibility: The quality of being trusted and believed in to a large degree defined by the characteristics of the information source (e.g., its method, claims to objectivity, and expert consensus)

Crossdisciplinary: Research practices that involve the input of multiple disciplines. Levels of integration vary from multidisciplinary, to interdisciplinary, to transdisciplinary (the most integrated form of crossdisciplinarity)

Decentralization: The process of redistributing or dispersing functions, powers, people or things away from a central location or authority

Deductive qualitative analysis: Theory-guided research; qualitative research guided by the top-down use of theory, hypotheses or sensitizing concepts

Deep core beliefs: Strongly held values and beliefs, relating to issues such as core political perspectives, inter-generational equity, and the existence of intrinsic environmental values

Deliberative governance: Also known as discursive democracy. A form of democracy in which deliberation is central to decision making. It adopts elements of both consensus decision-making and majority rule.

Demand characteristic bias: Introduction of bias to primary research whereby respondents form interpretations of question purpose

Demand-characteristic bias: Experimental artefact where participants form an interpretation of the experiment's purpose and unconsciously change their behavior to fit that interpretation

Devolution: The transfer or delegation of power to a lower level, especially by central government to local or regional administration

Diverger: Attitude towards the relationship of science with policy that emphasize the need to ‘bridge’ the gap between science and policymaking. Divergers typically follow linear narratives of instrumental impact, focused on the directly measurable impacts of a single evidence source. This position may be conceptualized as dichotomous, or zero sum, with evidence either having a direct and immediate influence on decision-making or having no impact at all

Ecological networks: A representation of the biotic interactions in an ecosystem, in which species (nodes) are connected by pairwise interactions (links). These interactions can be trophic or symbiotic.

Ecological resilience: The capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly

Ecosystem approach: An approach to conservation science and management based on the complexity and interconnectedness of natural systems in terms of their underlying functions.

Environmental economics: Interdisciplinary analysis of the economics of ecological systems, including the study of natural capital accounting and ecosystem service valuation

Ecosystem function: Biological, geochemical and physical processes and components that take place or occur within an ecosystem

Ecosystem service: Services which flow within and from natural systems, captured as benefits that flow from the environment to human socio-economic.

Ecosystem state: The tendency of a system to remain close to its equilibrium state, despite that disturbance (also known as ecosystem resistance)

Ecosystem structure: Pattern of interrelations of organisms in time and in spatial arrangements

Ecosystem-based management: Management solutions are associated with landscape scale conservation It aims to take a holistic approach, looking not just at biodiversity issues, but also issues such as local economies and agriculture, eco-tourism, geodiversity and the health and social benefits of the environment

Ecosystem: A biological community of interacting organisms and their physical environment

Entrepreneur/Entrepreneurship: Actors who play an important role in shaping policy-maker preferences by converting evidence into a policy-relevant form

Environmental Impact Assessment: Process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse

Epistemic authority: A person with extensive or specialized knowledge over the grounds of a body of knowledge, especially with reference to its limits and validity

Epistemology: The theory of knowledge, especially with regard to its methods, validity, and scope, and their relation to how one might discover knowledge about the world

EU Natura 2000: A network of protected sites within the European Union, consisting of an ecological network of protected areas, set up to ensure the survival of Europe's most valuable species and habitats. Natura 2000 is based on the 1979 Birds Directive and the 1992 Habitats Directive

Expertise-seeking behaviour: Collaboration between individual experts across different disciplinary fields

Feedback process: Process in which the effect or output of an action is 'returned' (fed-back) to modify the next action. Feedback is essential to the working and survival of all regulatory mechanisms found throughout living and non-living nature, and in man-made systems such as education system and economy.

Framework: A basic structure underlying a system used to identify relevant concepts and help organize analysis and theoretical comparison

Futurescape: A form of landscape-scale conservation that works in partnership with landowners to arrest species decline and reverse fragmentation of once widespread habitats

Gatekeeper: In the research setting gatekeepers are those who have the power and authority to grant or deny access to the researcher to a set population. In many cases gatekeepers are officials of institutions which are tasked to protect and serve the populations they oversee

Habitat: The natural home or environment of an animal, plant, or other organism

Humanities: Academic disciplines that study human culture. The humanities use methods that are primarily critical, or speculative, and have a significant historical element, as distinguished from the mainly empirical approaches of the natural sciences

In-house: Done or existing within an organization

Inductive qualitative analysis: Research that explores data for the emergence of concepts and ideas. Discourse is analysed within its own context rather than from a predetermined theoretical basis

Institutional analysis/level: Social science research which studies how institutions behave and function according. Applies to empirical and theoretical rules to understanding structures and mechanisms of social order and cooperation governing the behavior of two or more individuals

Instrumental impact: Also known as direct impact, for example, influencing the development of policy, practice or service provision, shaping legislation, altering behavior

Integrated Environmental Assessment: The process of producing and communicating future-oriented, policy-relevant information on key interactions between the natural environment and human society

Interdisciplinary: Research efforts that work jointly with more collaboration between disciplines but still with a clearly delineated disciplinary base

Intermittent variables: Defined as factors present in the social or political receptivity of scientific research that may occur at irregular intervals and in varying quantity. They may be sufficient factors to affect the way that new scientific information is utilized in the policy process, but not necessary to the uptake of that information. Quantification of factors that help to identify regularities that cast light on the complex interactions that constitute the negotiation of knowledge in the policy process.

Interpersonal collaboration: Practices and processes which includes communication and decision-making between a range of individuals, enabling a synergistic influence of grouped knowledge and skills

Interpretative methodology: Research that positions the meaning-making practices of human actors at the center of scientific explanation. Research does not start with concepts determined a priori but rather seeks to allow these to emerge from encounters in the field

Interview protocol: Structured set of interview questions tailored to the research aims and sample frame of the study

Intrinsic value: The value that that thing has in itself, or for its own sake, or in its own right.

Issue cohabitation: limited convergence exists at the deep core level,, but agreement exists at the policy core level

Knowledge broker: An intermediary, that aims to develop relationships and networks with, among, and between producers and users of knowledge by providing linkages, knowledge sources, and in some cases knowledge itself, to organizations in its network

Knowledge domain: the content of a particular field of knowledge

Knowledge use: The effective integration of knowledge by people or organizations. It is the result of understanding and application of knowledge and the knowledge gathering process

Landowners: A person who owns land, especially a large amount of land

Landscape scale: A conservation concept that takes a holistic approach, looking not just at biodiversity issues, but also issues such as local economies and agriculture, eco-tourism, geodiversity and the health and social benefits of the environment. Developed in response to the challenges of climate change and a perceived excessive focus on site based conservation.

Latent class: A set of observed (usually discrete) multivariate variables to a set of latent variables. It is a type of latent variable model. It is called a latent class model because the latent variable is discrete. A class is characterized by a pattern of conditional probabilities that indicate the chance that variables take on certain values

Legitimacy: Validity as judged by an external audience; the ability to be defended with logic or justification

Liberalism: Political philosophy or worldview founded on ideas of liberty and equality. Liberals espouse a wide array of views depending on their understanding of these principles, but generally they support ideas such as free and fair elections, civil rights, freedom of the press, freedom of religion, free trade, and private property

Likert-scale: A scale used to represent people's attitudes or agreement to a topic or set of statements

Limits to growth: Model of exponential economic and population growth with finite resource supplies used to simulate the consequence of interactions between the Earth's and human systems. Modelled the interaction of world population, industrialization, pollution, food production, and resource depletion, predicting overshoot and collapse of the global system by the mid to latter part of the 21st century

Linear model of impact: Traditional, instrumental conceptions of the role that evidence plays on societal decisions. Linear models typically envision two worlds: scientific knowledge producers, and policy knowledge users

Linguistic barriers to disciplinary integration: How language differs among disciplines, including how individuals from different disciplines had different understandings of the same specialist terminology.

Local Nature Partnership: Self-sustaining strategic partnerships of a broad range of local organisations, businesses and people with the credibility to work with, and influence, other local strategic decision makers to manage the natural environment as a system and to embed its value in local decisions for the benefit of nature, people and the economy

Logic model: Also known as a logical framework, theory of change, or program matrix; a tool used most often by managers and evaluators of programs to evaluate the effectiveness of a program

Manipulation: The process by which information is strategically manipulated to provide meaning, clarification and identity to allow the political construction of a problem

Marginal: The change in a final output or product that is produced by an increment of unit of another input or variable

Message-framing: Strategies of evidence use, presentation, and packaging for non-scientific audiences

Metanarrative: High-level theory that brings together evidence and concepts under the umbrella of one 'big story'

Metaphor: Policy narratives that draw comparison between one narrative and another. They assume certain similarities between situations, and imply prescription and judgments about the correct interpretation of knowledge

Methodological barriers to disciplinary integration: How methodologies differ among disciplines, including the systematic, theoretical analysis of the methods applied to each field of study

Methodology: The systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods, principles, tools and techniques of research associated with a branch of knowledge

Mixed-methods approaches: Research that includes a mixing of qualitative and quantitative data, methods, methodologies, and/or paradigms in a research study or set of related studies. If you visualize a continuum with qualitative research anchored at one pole and quantitative research anchored at the other, mixed methods research covers the large set of points in the middle area.

Model: A simplified description of a system or process, to assist calculations and make assumptions about particular objects of enquiry

Multidisciplinary: The most basic level of disciplinary integration, where teams work separately and in parallel within their own disciplinary bases

Narrative morals: Provide the argumentative logic behind policy actor mobilization of evidence. The moral of the story in a policy narrative is often portrayed to prompt action and as a policy solution

Natural capital stocks: Stocks of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. It is the extension of the economic notion of capital (manufactured means of production) to goods and services relating to the natural environment.

Natural capital: The stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. It is the extension of the economic notion of capital (manufactured means of production) to goods and services relating to the natural environment.

Natural science: A branch of science which deals with the physical world, e.g. physics, chemistry, geology, biology

Nature Improvement Area: Network of landscape-scale initiatives to improve ecological connectivity and reverse the decline in biodiversity across England

Negotiation: The negotiation of societal understanding around scientific concepts through simultaneous social processes of deliberation wherein science, society, and politics

Neoliberalism: Political and economic policies of economic liberalization policies based on neoclassical economic theory. Characterized by extensive economic liberalization, privatization, free trade, open markets, deregulation, and reductions in government spending in order to enhance the role of the private sector in the economy

Network bridge: In social networks, bridge relationships transmit information from one group to another. The breadth of information spread depends heavily on the number and connectedness of the bridges available to the originators of the information

New Public Management: Denotes broadly the government policies, since the 1980s that aimed to modernise and render the public sector more efficient and emphasizes efficient market-led delivery of public services

Non-government organizations (NGOs): a non-profit, voluntary citizens' group which is organized on a local, national or international level.

Ontology: Ontologies are used to formally represent knowledge within a domain. A formal, explicit specification of a shared conceptualization and assumptions about how the world is made up and the nature of things

Open-end questions: Questions that will solicit additional information from the inquirer. Sometimes called infinite response or unsaturated type questions. By definition, they are broad and require more than one or two word responses

Openness to change values: Grouping within the psychological study of values that relate to self-direction, stimulation, and hedonistic values

Order effect: Refers to how the positioning of question or tasks in a survey, test, etc., influences the outcome. This is designed to measure whether the order of the questions makes a difference in the outcome of the survey

Organizational cultures: The behavior of humans within an organization and the meaning that people attach to those behaviors. Culture includes the organization's vision, values, norms, systems, symbols, language, assumptions, beliefs, and habits

Parsimonious model: A model that accomplishes a desired level of explanation or prediction with as few predictor variables as possible. For model evaluation there are different methods depending on what you want to know

Personal beliefs/values: Core beliefs, values, and philosophies that we hold about life, its purpose, and our own purpose. Personal values influence how individuals interpret novel information and connect to issues of wider societal interest

Pluralism: A condition or system in which two or more states, groups, principles, or sources of authority coexist

Policy core beliefs: Values and beliefs specific to particular policy issues, relating to basic normative commitments and problem causality

Policy fling: Coalition interests converge only slightly at the policy core level there still can be situations where short-term motivations exist for transient cross-coalition arrangement in which partners unite around a shared set of short-term material interests.

Policy partnership: Sustainable policy partnerships overlap or converge on deep core, policy core, and implementation-oriented secondary beliefs. Core values are shared and help partners align interests over the long-term High levels of alignment increase policy partnership longevity.

Policy subsystem: Subsystems within a broader political environment defined by relatively stable parameters and external events, and constrained by long-term coalition opportunity structures, short-term constraints and resources of subsystem actors, and other policy subsystem events

Policy-makers: At the simplest level, a person responsible for or involved in formulating policies, especially in politics

Policy-making: The act of creating laws or setting standards for a government or business.

Policy: a course or principle of action adopted or proposed by a government or an organization

Polucy entrepreneur: Political actors who promote policy idea and who seek to initiate dynamic policy change. Broadly, an individual who changes the direction and flow of politics

Positivism: A philosophical system recognizing only that which can be scientifically verified or which is capable of logical or mathematical proof, and therefore rejecting metaphysics and theism

Primary research: New research, carried out to answer specific issues or questions. It can involve questionnaires, surveys or interviews with individuals or small groups

Procedural barriers to disciplinary integration: Organizational, leadership, and process arrangements that restrict the flow of information between experts of different disciplinary backgrounds

Professional beliefs/values: Expectations are based on what the professional group has agreed are the most important values, or virtues, to be maintained

Public consultation: Regulatory process by which the public's input on matters affecting them is sought. Its main goals are in improving the efficiency, transparency and public involvement in large-scale projects or laws and policies.

Public policy analysis: Set of tools and frameworks for determining which of various alternative policies will most achieve a given set of goals in light of the relations between the policies and the goals. Analysis of policy may be analytical and descriptive (i.e., attempts to explain policies and their development) or prescriptive (i.e., involved with formulating policies and proposals)

Public values: Societal values providing normative consensus about 1) the rights, benefits and prerogatives to which citizens should (and should not) be entitled; 2) the obligations of citizens to society, the state and one another; 3) the principles on which governments and policies should be based

Qualitative analysis: Exploratory research used to gain an understanding of underlying reasons, opinions, and motivations. It provides insights into the problem or helps to develop ideas or hypotheses for potential quantitative research; includes compositional and observational methods

Quantitative analysis: Systematic empirical investigation of social phenomena via statistical, mathematical or numerical data or computational techniques

Research impact assessment/evaluation: Impact evaluation assesses the changes that can be attributed to a particular intervention, such as a project, program or policy, both the intended ones, as well as ideally the unintended ones. Impact evaluations seek to answer cause-and-effect questions. In other words, they look for the changes in outcome that are directly attributable to a program.

Research prioritization: One of the key nodal points in the research policy planning cycle, which encompasses research planning, research priority setting, strategies and implementation of research priorities, research utilization, research monitoring and evaluation, and overall research policy management

Research users: Practitioners in academia, policy, practice, and commercial background who utilize the outputs of scientific research

Rhetorical devices: Narrative strategies used by policy actors to expand their power and ultimately win in the policy process

Salience: How relevant information seems to an audience

Scaling-up: Strategic narrative technique that raises the perceived importance of an issue by associating it to problems of greater perceived societal weight.

Science and Technology Studies: The study of how social, political, and cultural values affect scientific research and technological innovation, and how these, in turn, affect society, politics and culture.

Science-policy gap: The interchange of knowledge between different institutional 'worlds' or 'communities', typically portrayed as between the 'creators' (e.g. science) and the 'users' (e.g. policy) of knowledge.

Science-policy interface: Social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co- evolution, and joint construction of knowledge with the aim of enriching decision-making

Scientific method: A method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.

Secondary beliefs: A narrow set of values and beliefs, typically focusing on how core beliefs should be implemented in practical policies.

Self-enhancing values: Grouping within the psychological study of values that relate to materialism, desire for power, and personal ambition

Self-reported data: Information that program participants generate themselves that is used to assess program processes or outcomes

Self-transcending values: Grouping within the psychological study of values that relate to universalism, benevolence

Semi-structured interview: Method of research used in the social sciences. While a structured interview has a rigorous set of questions which does not allow one to divert, a semi-structured interview is open, allowing new ideas to be brought up during the interview as a result of what the interviewee says

Social capital: The networks of relationships among people who live and work in a particular society, enabling that society to function effectively. Social capital is the expected collective or economic benefits derived from the preferential treatment and cooperation between individuals and groups

Social contract theory: The view that persons' moral and/or political obligations are dependent upon a contract or agreement among them to form the society in which they live

Social network analysis: Methodology for analyzing the structure of whole social entities as well as a variety of theories explaining the patterns observed in these structures

Social science: The scientific study of human society and social relationships

Socio-ecological system: Consisting of a bio-geo-physical unit and its associated social actors and institutions. Socio-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context

Sociodemographic background: Socioeconomic characteristics of a population expressed statistically, such as age, sex, education level, income level, marital status, occupation, religion, birth rate, death rate, average size of a family, average age at marriage.

Species: A group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding

Stages heuristic: A theory regarding policy process according to which policy is divided and analysed in several stages. The most common stages are: problem formation, selection of policy, implementation, and evaluation

Stakeholder engagement: The process by which government or organisations involve people who may be affected by the decisions it makes or can influence the implementation of its decisions.

Step change: A change point of discontinuity in a system, leading to a change in level or a change in trend of the system

Strategic narratives: Strategic use of policy narratives that serve as independent variable(s) of interest on policy outcomes

Structured interview: Also known as a standardized interview or a researcher-administered survey; a quantitative research method commonly employed in survey research. The aim of this approach is to ensure that each interview is presented with exactly the same questions in the same order

Substantive issue: Relating to, containing, or being the essential element of a thing

Sustainability: The endurance of systems and processes. In ecology, sustainability refers to how biological systems remain diverse and productive. In societal and economic framings sustainability is captured by sustainable development across four interconnected domains of ecology, economics, politics and culture

Sustainable development: a road-map, or action plan, for achieving sustainability in any activity that uses resources and where immediate and intergenerational replication is demanded. Sustainable development is the organizing principle for sustaining finite resources necessary to provide for the needs of future generations of life on the planet

Symbolic impact: Also known as partisan impact: Knowledge acting as a resource used to support vested political interests, to justify a pre-existing position, or justifying inaction on other fronts

Synergy: The interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects

Synthesis report: Critical synthesis of a body of evidence or literature by comparing, combining and contrasting methods and findings. The output combines the constituent elements of separate material or abstract entities into a single or unified entity

Systems paradigm: A way of thinking about the strategic environment, and how to develop processes in organizations that achieve strategic goals

Team science: Conceptual and methodological strategies aimed at understanding and enhancing the processes and outcomes of collaborative, team-based research.

Temporal marker: In linguistics, a statement that helps define when an event happened. In this study, the term is applied to temporal points in the policy development process to which interview respondents were asked to relate their responses to

Theory: A supposition or a system of ideas to make general assumptions about the causal relationships between concepts, generally based on general principles independent of the thing to be explained.

Total Economic Value: A concept in cost benefit analysis that refers to the value derived by people from a natural resource, a man-made heritage resource or an infrastructure system, compared to not having it

Traction: The degree to which a new idea or information is accepted by the public or decision-makers

Traditional values: Grouping within the psychological study of values that relate to conservative beliefs around duty, family loyalty, and social order

Trans-scientific: Inputs on areas of policy that go beyond their own expertise, but whose scientific credibility contribute to the political construction of new Knowledge

Transaction costs: In economics and related disciplines, a transaction cost is a cost incurred in making an economic exchange (restated: the cost of participating in a market)

Transdisciplinary: Research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem.

Translation: Process in the coproduction of knowledge whereby information is framed for public consumption, experts problematize observed facts, and by extension make themselves indispensible in the solution

Typology: A classification according to general type, especially in archaeology, psychology, or the social sciences

Unidisciplinary: Research practices that involve the input of only a single discipline

Universal values: Something is of universal value if it has the same value or worth for all, or almost all, people. This claim could mean two importantly different things. First, it could be that something has a universal value when everybody finds it valuable. Second, something could have universal value when all people have reason to believe it has value

Utilitarianism: A theory in normative ethics holding that the proper course of action is the one that maximizes utility, usually defined as maximizing total benefit and reducing suffering or the negatives.

Venn diagram: A diagram representing mathematical or logical sets pictorially as circles or closed curves within an enclosing rectangle (the universal set), common elements of the sets being represented by intersections of the circles

Web research: The practice of using Internet information, especially free information on the World Wide Web, in a focused and purposeful way in research

White Paper: White papers are documents produced by the Government setting out details of future policy on a particular subject. A White Paper will often be the basis for a Bill to be put before Parliament, but the Natural Environment White Paper was designed to set clear high-level policy direction for the environment in local and national decision-making.

Wicked problem: Originally used in social planning to describe a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize

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