Exploring the Socio-Material Boundaries of Climate Change Resilience

Abstract

This paper focuses on the status of resilience for conceptualizing interactions on climate change response between actors possessing differing social standpoints and worldviews. Relations between discursive mobilizations and socio-material manifestations of resilience are considered. The paper reviews and builds upon research which has addressed environmental and scientific issues using the concept of the boundary object and related ideas. Examination of wider literature reveals a series of themes - power and authority, epistemological interactions, reflexivity, and scale - which make visible an array of variables, and which could facilitate more systematic and comparable studies of climate change resilience.

Keywords: Resilience; Boundary Objects; Boundary Work; Co-production; Climate Policy

Introduction

This paper examines how the term 'resilience' represents and intervenes in relation to climate change responses. Resilience has become increasingly prominent in discussions around climate change, and policymakers have adopted such language (Adger et al 2011). This however has raised concerns over whether resilience has simply become a fashionable term which has merely been substituted for previous discourses (Weichselgartner and Kelman 2015). On the other hand, the 'increased vagueness and malleability' of resilience has been posited by Brand and Jax (2007), as a possible advantage which may 'foster communication across disciplines and between science and practice' (Brand and Jax 2007, 23). Meanings and framings of resilience however vary considerably among different policy and academic fields (Brown 2014, p.108). These may reflect a wide range of emphases, such as adaptation,

vulnerability, security, or critical infrastructures, which poses a challenge to producing comparable studies.

Some interpretations of climate change resilience have been criticised for tending to adopt 'technical-reductionist' frameworks (Weichselgartner and Kelman 2015), with its social dimensions only having recently received attention (Brown 2014). The impact of climate change on the livelihoods of vulnerable communities is one significant concern. A livelihoods-based approach has recently been proposed as a means of merging interests and discourses around the possibility of climate change and development policies better attuned to the needs of vulnerable communities (Tanner et al 2015). Livelihoods approaches, relating broadly to the capabilities, assets and activities necessary for a means of living (Ayeb-Karlsson et al 2015), encompass a variety of themes which cut across research, policy and practice on climate change. Livelihood systems may involve a range of activities vital to communities, encompassing socio-economic activity, food and water supplies, environmental and cultural heritage, and the maintenance of kinship networks. Livelihoods approaches also encompass other matters of political economy, concerning power, institutions and law (such as the role of nation states and evolving social contracts) (Ayeb-Karlsson et al 2015; Tanner et al 2015).

A development related to resilience and livelihoods concerns the rising prominence of loss and damage in recent climate change negotiations (Huq et al 2013). There has been increasing concern over the social dimensions of loss and damage brought about by environmental stressors (Morrissey and Oliver-Smith 2013; Warner et al 2013). Livelihood resilience has been framed as a function of the extent of losses and damages experienced by vulnerable communities (Tanner et al 2015). The issue of how communities cope with environmentally-induced loss and damage invites consideration of the kind of interventions which might promote forms of resilience. Such interventions may take a multiplicity of forms, including new laws and regulations, through to policy tools for social protection such as community-

based early-warning systems (Ayeb-Karlsson 2015 et al). Other interventions may encompass measurement methods such as vulnerability indices, or new ways of utilizing existing information, such as the use of mobile phone data to monitor population movement (Flowminder 2014). Micro-insurance is another form of intervention, which involves schemes aimed at protecting very low-income individuals and households through affordable premiums (Ayeb-Karlsson et al 2015). Micro-insurance may be used for example to cover the loss of a single farm's crops from an adverse climate event.

The social, political, technological and material consequences of resilience discourses may mobilize and circulate among publics, policymakers, practitioners, and researchers. Such groups may exhibit notable heterogeneity in terms of their standpoints and knowledge systems, and involve distinct but interacting socio-cognitive domains, including branches of science, politics, law, religion, economics etc. Various interpretations of 'resilience' may circulate among diverse 'epistemic communities' (Haas 1992) or 'epistemic cultures' (Knorr-Cetina 1999). While the interpretive flexibility of resilience has been claimed to be potentially advantageous (Brand and Jax 2007), its mobilization raises issues of aims and consequences. Concerns have been expressed that the term 'resilience' is susceptible to being politically exploited (Welsh 2013). Resilience discourses have been critiqued for potentially justifying vested policy interests or the political status quo. For example, associating resilience with the ability for societies to return to a perceived 'normal' state could be interpreted as reflecting a politically conservative orientation. Alternatively, associating resilience with individual capacity to respond to climate change events, could possibly reflect neoliberal-type discourses promoting the abrogation of responsibilities by the State (Tanner et al 2015). A focus on the social dimensions of climate change resilience therefore raises political questions, such as resilience for whom, and in what form (Gillard 2016). One may also question whether specific attempts to promote 'resilience' are appropriate or necessarily acceptable to all those affected.

Some criticisms have revolved around the perceived risk that the employment of resilience discourses in policymaking may lead to suboptimal outcomes or perpetuate existing power differentials (Weichselgartner and Kelman 2015). It is therefore important to consider the socio-political implications of mobilizing resilience as a specific form of discourse.

This article seeks to avoid essentializing resilience. Instead it is argued here that resilience is best framed as a temporally and spatially contingent concept which is both driver and outcome of specific configurations of human and non-human entities (Law and Mol 1995; Latour 1999). In adopting such a position, the article focuses on the mobilizing qualities of 'resilience' discourses, and how they may link human and non-human elements in heterogeneous assemblages (Callon 2007) which construct and promote specific understandings of 'resilience'. Such understandings may also inter-relate with other emergent discourses such as environmental loss and damage. This article takes the view that comprehending resilience, using concepts from social boundaries research as analytical framings, can illuminate the contingent relationship between discourse and inter-related social and material orderings. The paper advocates more comparable studies of the boundary properties of climate change responses. It considers a series of factors which may influence the way in which the notion of resilience represents and intervenes, in order to identity potentially fruitful points of comparison between cases.

This article also addresses concerns regarding the apparent tendency to privilege 'technical-reductionist' framings of resilience over its social dimensions (Weichselgartner and Kelman 2015). In particular the tendency of scientific framings to claim a representative privilege is questioned. Instead, it is suggested here that 'resilience' is better conceptualized as a performative signifier. Interventions in the name of 'resilience' between heterogeneous actors may directly impact upon social and material orderings (Law and Mol 1995; Callon 2007).

The paper proceeds as follows. The following section draws upon Science and Technology Studies (STS) literature to outline arguments for the contingency of relations between discourse and socio-materiality. Links between these and ideas from socio-ecological systems (SES) literature are briefly drawn. A subsequent section critically reviews key concepts which have emerged from social boundary studies, including the notion of boundary work, and boundary objects, infrastructures and organizations. Further opportunities to utilize these theoretical tools to critically study climate resilience are then explored. Through an examination of wider literature and other sources, a series of themes, namely *power and authority*, *epistemological interactions*, *reflexivity* and *scale* are identified as possible pathways for the production of comparable studies.

The 'Co-production' of Knowledge and Socio-Material Orderings

STS research has questioned the notion that science uncovers and represents pre-existing, objective 'realities'. Instead, a notable vein of STS research has suggested that realities are actively brought into being through scientific interventions (Law and Mol 1995; Callon 2007). The relations between discourses, knowledge, materiality and power has received growing attention from STS (Pinch and Swedberg 2008; Faulkner and Lawless 2012). These works emphasise inter-relations between material practices and collectivities of perceptions, attitudes and ideas.

Socio-ecological systems (SES) literature has for some time also explored the relationship between ideas, institutions, and the material conditions of existence (Jamieson and Lovelace 1985; Folke et al 2007, 30). As Folke et al (2007) assert for example:

> 'We abandon simple ideas of environmental or social determinism, and of human/nature independence, in favour of a co-evolutionary view of the origin and

> maintenance of ideas, institutions, resources, and societies. The biophysical world is not seen as a single strong determinant of social mechanisms, but neither is it passively moulded by human ideas and actions, nor is it simply a backdrop against which the human drama unfolds.' (Folke et al 2007, 49).

The assertions of Folke et al suggest the potential of re-visiting the relationship between society and ecology, open to the notion that humanity's perception of, and interaction with, the environment shapes decision-making processes and *vice versa*. Much STS research aligns with the words of Folke et al through the concept of 'co-production' used to frame the interdependent relationship between science and environmental policies (Jasanoff 2004; Miller 2004).

STS research has also indicated that scientific knowledge is constructed in social systems where differing epistemologies exist, but which are bestowed with broadly equal authority. Law, for example, is predicated on a markedly different set of epistemological practices (precedent and procedure rather than theory and experiment), yet has been shown to play a key role in shaping scientific knowledge in judicial and regulatory contexts (Jasanoff 1990; Irwin et al 1997; Lynch and McNally 2003; Lawless 2013). These kinds of studies illuminate how judgements over what is perceived as valid 'scientific' knowledge in the context of other social worlds such as law, may be notably contingent. Research has also explored the ways in which actors negotiate, shape or seek to transcend epistemic boundaries between social worlds such as science, law, politics or commerce. The concept of boundary work has sometimes been utilized in such studies. Attempts to negotiate between social worlds have often been perceived to involve the emergence of so-called boundary objects, boundary infrastructures, or boundary organizations. These concepts are outlined in what follows.

Constructing and Transcending Boundaries

The concept of *boundary work* was used by Gieryn (1983) to describe how the demarcation of 'science' from 'non-science' is better considered an empirical, rather than an analytic issue (Gieryn 1983, 1999), and that the construction of such boundaries is highly contextualized. In addition to addressing the demarcation of 'science' from 'non-science' in various contexts (Gieryn 1999), the boundary work concept has been applied to study how the relationship between science and politics is negotiated. Boundary work has been used as a means of understanding how actors identify and define matters of scientific priority (Gieryn 1983); how they make strategic divisions of responsibility between science and politics in regulatory decision-making (Jasanoff 1990); and how scientists distinguish their research from their employer's politics (Clark et al 2016). The concept has been utilized in environmental studies (Guston 1999, 2001; Eden et al 2006; Clark et al 2016). In their study of environmental non-governmental organizations (NGOs), Eden et al (2006) for example found that these groups, while acknowledging the epistemic authority of science, were versatile and pragmatic in the way in which they legitimated knowledge and expertise from different sources, which involved various strategies (Eden et al 2006).

While boundary work studies originally focused on the demarcation of epistemological boundaries, other research has highlighted how such boundaries may be transcended. A rich vein of research has explored how actors co-operate while they continue to inhabit different socialized worldviews. From these studies a number of concepts have emerged, including boundary objects, boundary infrastructures and boundary organizations.

Star and Griesemer's (1989) historical-ethnographic study of the University of Berkeley's Museum of Vertebrate Zoology (MVZ) is generally credited with introducing the concept of the *boundary object*. They describe boundary objects as those which may exist where different

social worlds intersect. Star and Griesemer saw boundary objects as being produced when various actors undertake collaborative representative practices even when their perceptions diverge. Their study also indicated how the act of creating representations via boundary objects may create new networks and possibilities. Star and Griesemer described the MVZ as a boundary object which co-ordinated the activities of academic zoologists, university administrators, amateur wildlife enthusiasts, hunters, and others. The MVZ was perceived in different ways: as a way of preserving California's natural history by amateur enthusiasts, a material asset by university administrators, and as a site of research work by academic zoologists.

Trompette and Vinck (2009) summarize boundary objects thus:

> 'The notion is used to describe how actors maintain their differences and their cooperation, how they manage and restrict variety, how they coordinate in space and time. It qualifies the way in which actors establish and maintain coherence between interacting social worlds, without making them uniform or transparent from one to the other. Actors in these social worlds can, thanks to the boundary object, negotiate their differences and establish agreement on their respective points of view.' (Trompette and Vinck 2009, 5)

While resilience has itself been regarded as a boundary object (Hutter et al 2013), it may also facilitate the emergence of boundary objects. For example weather forecasting tools could function as boundary objects to facilitate the timely release of micro-insurance compensation in the event of drought.

The boundary object became 'annexed to the initial, major issue of the role of infrastructures in communities of practices and in coordination between heterogeneous worlds.' (Trompette

and Vinck 2009, 5). The construction and maintenance of information across collectives is a notable theme of subsequent work by Star and colleagues, who introduced the notion of *boundary infrastructures* (Star and Ruhleder 1996; Bowker and Star 1999). The boundary infrastructure concept captures the 'the institutionalization of categorical work across multiple communities of practice, over time' (Bowker and Star 1999, 287). Bowker and Star argue that boundary infrastructures are assemblages of actors and things which structure knowledge and understanding. They span 'larger levels of scale than boundary objects' (ibid). Boundary infrastructures may stabilize the production and management of information, involving practices of classification or categorization (Trompette and Vinck 2009).

The boundary infrastructure concept has been used to analyse how cognitive and social orderings are simultaneously shaped across space. Boundary infrastructures may arise with a particular vision in mind (Park 2010), or they may emerge more responsively, as in the identification of mobile phone data as a means to understand patterns of communication and social networks following disruptive environmental events (Flowminder 2014). Of further significance is the balance between intended aims and subsequent consequences. Boundary infrastructures may manifest themselves in efforts to uphold or challenge political orders, requiring the projection of visions to persuade actors to invest in them, a process which may involve rhetoric and political persuasion (Sovacool and Brossman 2013). This may involve a degree of performativity, bringing sociotechnical realities into being through a combination of engineering ingenuity and policy entrepreneurship (Hughes 1983).

Boundary infrastructure research has also drawn attention to the host of unforeseen technical and logistical problems which might emerge in the course of their implementation (Star and Ruhleder 1996). The lesson from such research is that the challenges of facilitating resilience via social and technological means may be dependent on a host of complex interactions

between people and objects. These interactions are themselves shaped by, and serve to shape, spatial and cultural connections. A sense of individual resilience could reflect a strong sense of identity and shared culture (Ayeb-Karlsson et al 2015, 25), which in turn could be fostered by connections to home or community through communications infrastructures. Interventions which seek to connect actors may identify new challenges which need to be resolved. The identification of these problems, and their resolution, could be said to constitute a kind of shared learning process.

Theoretical tools such as boundary objects and boundary infrastructures have facilitated understanding of how relations between different actors may be stabilized, possibly requiring organized activity to bring about certain states of affairs (Guston 2001). Such activity might promote opportunities to shape and use boundary objects or develop incentives to promote them. Concerted activity might also be needed to bring together different actors and encourage participation in practices which transcend socio-cognitive boundaries. Certain fora might stabilize understandings of accountability and responsibility between different actors brought together to work on specific issues.

Boundary organizations have been defined as bodies which 'mediate between different social worlds and communities to bring people on either side of a boundary

together to increase mutual understanding of one another's perspectives, capacities and needs while allowing individuals within the organization to remain within their respective professional boundaries and to maintain their responsibility to their different constituencies' (Franks 2010, 286). Such organizations may also allow the boundaries around an issue to be negotiated (Cash 2001, 450), which might involve defining the issue under consideration (i.e. a working definition of 'resilience' or 'loss and damage'). Boundary organizations may determine which actors are perceived relevant to an issue, and the means by which an issue is

discussed. The negotiation of such boundaries may also serve to mould the identity and practices of the organization in return (Bartel 2001; Lorenzoni 2007, 68). Boundary organizations could also be construed, at least in certain situations, as boundary objects themselves (Moore 1996).

In some cases boundary practices (be they in the form of boundary work, or boundary objects, infrastructures or organizations), may emerge as a response to a recognised issue. In other examples boundary encounters may re-occur with relatively little conscious reflection on the part of actors representing differing institutions (Edmond 2000), which may be a consequence of norms and procedures reflecting the 'social facts' (Durkheim 1982 [1895]) of institutions such as law, science, religion etc. This distinction has been largely overlooked so far, yet it raises important issues. These include the identification or non-identification of specific problems, and the perception or non-perception of opportunities for boundaries to be transcended. These in turn highlight the influence of wider institutional barriers and drivers in shaping or hindering interactions.

Structural socio-political factors may be significant when considering boundary practices associated with manifestations of resilience (Weichselgartner and Kelman 2015). These are however sometimes marginalized in studies which have tested boundary concepts against specific empirical examples, or have taken a grounded theory approach to characterize boundary concepts in case studies. While such work has added variety and richness to boundary studies, research has led to various framings which only partially overlap.

More attention could also be paid to the possibility that ostensibly united and harmonious communities depend on boundary objects or infrastructures which are unrecognised as such under stable conditions (Weichselgartner and Kelman 2015). The existence of boundary objects and boundary infrastructures may only become visible following a disruptive event, whereas in normal circumstances they may be taken for granted by communities. Social-

structural tensions or relations may be latent until boundary objects or infrastructures become absent or malfunction following disruptive events.

The following sections have sought to indicate how resilience can be thought of as encompassing a series of enactments, or mobilizations, which may influence socio-material orderings. These enactments may involve various socialized worldviews interacting. Boundary concepts have however been utilized by researchers in a variety of different ways, which may impede meaningful comparisons between studies.

In what follows the article explores the way in which resilience discourses may be co-produced with instances of boundary work, objects, infrastructures and organizations (collectively referred to here as 'boundary practices'). The next section explores the possibilities of using boundary practices as analytical foci for studying the construction and consequences of resilience discourses. An examination of literature reveals a series of themes - power and authority, epistemological interactions, reflexivity and scale – which represent promising avenues for further study of the boundary properties of climate resilience discourses. These themes have also been illuminated in discussions organized by the United Nations University Resilience Academy, an international network including scientific researchers, policymakers and NGO practitioners. Through seeking to identify research possibilities relating to those themes, the next section sketches an agenda to facilitate more systematic and comparative study of resilience.

Toward More Systematic Boundary Analyses of Resilience

Power and Authority

The role of power and authority in the construction of certain distinctions, such as those between 'science' and 'non-science', or 'scientific' versus legal reasoning, is an enduring

theme of studies which have used boundary work to frame interactions between actors deliberating claims to knowledge within various settings (Gieryn 1983; Lynch and McNally 2003). As Clark et al (2016) observe in their field study of 'Alternatives to Slash and Burn', a scheme to promote environmentally-sustainable farming, managing power relations 'appears to be essential to good boundary work' (Clark et al 2016, 4621). Their study found that claims to epistemic authority via recourse to science were sometimes viewed suspiciously by rural land users as a means of control by state and business interests.

While the relationship between power and boundary practices has been recognized, this theme merits further exploration in relation to climate resilience. The exercise of power and influence, in the form of calls to law, regulations, sanctions, incentives etc., as impacting upon the emergence or non-emergence of boundary objects represents a possible pathway for further research. The presence of rules, sanctions or incentives may involve boundary practices creating new spaces of possibility, such as the creation of boundary organizations in the Netherlands to assist farmers in developing innovations to work within environmental prescriptions (Franks et al 2010). In other cases vested interests (which may involve threat of sanctions) may serve as possible barriers to boundary practices. For example, Clark et al (2016) found that many scientists working with Alternatives to Slash and Burn at the local level were employed by national ministries or international NGOs that had political agendas of their own. This relationship called into question local scientists' ability to make a truly independent contribution to participatory work.

Boundary practices may exert influence through creating new rules, sanctions or incentives (Guston 2001; Franks 2010), such as the revision of rules of forest tenure in Indonesia as described by Clark et al (2016). Micro-insurance schemes can provide group incentives for farmers if they agree collectively to minimize crop exposure risks to drought. These schemes may be organized by boundary organizations which link communities and scientists such as

meteorologists. Boundary organizations may exert power through holding individuals accountable with the ultimate sanction of dismissal, as in the example of 'county agents', intermediaries employed by land-grant universities to engage scientists and farmers on water use (Cash 2001, 440). Boundary organizations, if suitably empowered, could present credible threats to withdraw their interventions, possibly leaving one or more stakeholders at a recognized disadvantage (Clark et al 2016). Sanctions and incentives may be formalized, but they may alternatively be tacitly embedded in societies which ethnographic approaches may be well-suited to identify.

The issue of loss and damage which has emerged in climate change negotiations illuminates power dynamics surrounding the attempted mobilization of specific resilience discourses. Loss and damage has been framed as relating to the claimed adverse effects of climatic stressors occurring despite mitigation and adaptation efforts (Huq et al 2013). The 2015 Paris Climate Change Agreement recognized 'loss and damage' as distinct from 'adaptation'. Efforts to link loss and damage with resilience have involved advocating new laws and regulations to protect vulnerable peoples. Those advocating a distinct loss and damage agenda have had to contend with powerful opponents. The loss and damage discourse has faced resistance from developed countries, who have often perceived it in terms of attributing blame and demanding compensation.

Investigating the role of power and authority also raises issues of possible incentivization and duress in shaping 'resilient communities'. Research utilizing the boundary object concept has tended to underplay the possibility that some actors may remain silenced or marginalized (Tanner et al 2015). Recognising and evaluating feelings of powerlessness is a challenge for those seeking to formulate qualitative assessments of loss and damage, which could involve the negotiation of boundaries between publics, policymakers and researchers. While some individuals may actively mobilize resilience discourses, others may become subject to

discourses impacting without prior consent. Boundary objects, infrastructures or organizations related to resilience may be perceived to be more or less powerful, or may make power visible. For example, the deployment of a framework tool used to monitor food security in Honduras, highlighted how the palm oil industry threatened food security through buying up land (Bizikova et al 2016).

The relational status of individuals caught up in the co-production of resilience discourses and boundary practices is a potentially significant theme. The social status of, and potential inequalities between individuals, (in terms of e.g. gender, ethnic, social class differences, access to education etc.) involved in mobilizations of climate resilience has so far been largely under-explored. Boundary studies could also consider power in the form of resources, or the role of social, human, financial, environmental and physical capitals (Mayunga 2007) in shaping interactions between actors and entities across spaces (Keck and Sakdapolrak 2013).

Studies have also tended to focus on legitimized activity, yet the possibility remains that illicit or illegal activities, and possibly also corruption, favouritism etc., may affect mobilizations of resilience. Illicit activities may shape interpretations and mobilizations of climate change resilience, such as how to combat links between narcotics crime and deforestation (McSweeney et al 2014).

Epistemological Interactions

Power may reside in a variety of institutions or social worlds, with different ways of producing claims to knowledge (Cash 2001). Institutional epistemologies may create tensions and uncertainties when they interact (Edmond 2000; Lynch and McNally 2003). For example law, at least in the Anglo-American tradition, has been associated with procedure and process, whereas science, broadly construed, has been associated with hypothesis,

numerical reasoning and progress (Schuck 1993; Goldberg 1994). Interactions between spheres such as science, politics, law, commerce etc. is a core theme of studies which have addressed how boundaries within and between these domains are challenged and constructed (Gieryn 1983; Guston 1999; Kaufmann and Todtling 2001; Lynch and McNally 2003; Lawless 2013). Epistemological differences manifest themselves in matters of climate change resilience and loss and damage, given that they encompass various actors, including scientists, NGO practitioners, governments and publics. These differences are exploitable. As Clark et al (2016) observe, science can be appropriated by policymakers to support decisions already made, or they may repackage questions of environmental justice as technical issues to be resolved by scientists under their control.

Different approaches to measurement of environmental impact may reflect different institutionalized expectations about knowledge production. Assessing loss and damage can alternately be measured in either financial or non-financial terms (Morrissey and Oliver-Smith 2013). The latter may be framed in terms of human and social costs to health, access to education, or feelings of powerlessness or dependency. Non-numerical evaluations of loss and damage may be preferred by some actors, while others, such as quantitative researchers or those in financially-related fields, may favour numerical framings.

Less formalized institutional epistemologies should also be considered. The implicit norm of interpretive flexibility which characterises the wording of international political agreement contrasts with the precision of scientific research. Institutional epistemologies represent important framings which may influence the way in which power is exercised. They may be formally stated or may be tacit.

Rather than new boundary objects or organizations emerging, institutions might try and change from within by re-interpreting existing rules or procedures. Specific domains or disciplines

should not themselves be regarded as monolithic, and may themselves exhibit considerable epistemic and social heterogeneity. Actors may be more or less conscious of epistemological differences between different social worlds. Context may influence the extent to which actors are *reflexive* about disciplinary relations in specific cases, which points to another notable theme.

Reflexivity

In a given situation, resilience discourses may manifest themselves with more or less a sense of conscious design, (Tanner et al 2015). Actor's expectations may vary, and they may be more or less conscious of a particular issue as they participate in certain activities. Boundary practices may involve some participants acting in an entrepreneurial or brokering fashion, while others may be less consciously aware of an overall vision (Star and Griesemer 1989).

While actors may be conscious of particular institutional regimes, and related rules and procedures, they may exhibit varying awareness of incommensurabilities between institutions. Issues between different communities of practice may be routinely experienced with or without the conscious move toward an inclusive solution in the form of boundary objects, infrastructures or organizations. This has often been shown to be the case in studies of science-law interactions (Edmond 2000). Appeals to *a priori* authority may replace any sense of individual agency.

Exploring livelihoods and resilience invites a reflexive posture towards the methods by which the social dimensions of resilience are measured or evaluated. Quantitative methods may be favoured due to the seeming universality of numbers, yet the tendency to trust numbers might also conceal highly contingent, localized practices (Latour 1987). Assessing damage, or the loss of livelihood, may only be partially captured through purely quantitative methods.

Damage to individuals and communities could be indirect, involving knock-on economic impacts. Loss of land and forced migration through environmental impacts may not only have economic consequences (e.g. the need to find different employment), but could also lead to loss of identity or place-attachment (Ayeb-Karlsson et al 2015, 25).

Scientific data may become perceived differently in the light of a particular disruptive event. Wynne's study of interactions between sheep farmers and UK government scientists following the 1986 Chernobyl disaster is instructive (Wynne 1996). In this case scientists assumed their findings were reliable even when farmers, who were later vindicated, had reason to reject their representative claims. In cases where data is disputed between scientists and lay communities, policymakers may be caught somewhere in between. This in turn may obscure understanding of a particular ongoing socio-ecological event. Reflexive boundary work could draw attention to the potential limitations of methods for producing knowledge, which could be ameliorated through multidisciplinary and participatory methods (Ayeb-Karlsson et al 2015).

The presence or absence of systems for reflection or collective learning may be significant (Tàbara 2013). Comparative studies of learning and problem resolution among heterogeneous actors, using boundary work and boundary objects as analytical foci, could help make socio-cognitive barriers visible, and possibly identify practices of inclusion and exclusion in deliberations over climate change and resilience issues.

The development of learning systems may represent the traversing of certain boundaries itself, for example in the form of boundary organizations, but there may already be systems in place within existing organizations or structures (Bartel 2001). The presence or absence of these systems could be significant in that they may influence the progress of future boundary interactions. The presence of *a priori* envisaged aims is another potentially relevant variable. Certain activities may reflect potentially competing interests. The ways through which actors understand their own interests, and how the aims and potential consequences of achieving them

(or not), are understood, may vary from case to case. The ways in which interests are understood and articulated may also have a key bearing on outcomes (Carlile 2004). The extent to which actors understand the interests of others may vary, with notable consequences (Fischer 2001).

The loss and damage concept displays a degree of reflexivity on the part of actors trying to promote it in climate change agendas, due in part to the significant degree of political opposition they have sometimes faced. The way in which certain countries have organized themselves to promote a loss and damage agenda has been instrumental in gaining recognition of the latter issue. Like 'resilience', the interpretive flexibility of the term 'loss and damage' has been reflexively utilized in certain fora. Punitive interpretations of loss and damage (such as liability and compensation) have been consciously downplayed in favour of representing it as a focus for more constructive deliberation. Loss and damage can be linked with the language of opportunity, which may encompass terms such as resilience to advocate for new policy tools and regulations.

Scale

Scale is a notable aspect of the study of representations and mobilizations of resilience (Weichselgartner and Kelman 2015). Issues of scale are reflected in the boundary infrastructures and organizations literature. Cash (2001), for example, in his study of US agricultural boundary organizations, suggests that such organizations may help to define the scale of a problem by negotiating boundaries between levels (such as community, county and state level), and mediate information flows across them.

Scale encompasses descriptive and normative dimensions. For example, environmental stressors may have different impacts at the level of the individual or the nation-state. In

Bangladesh for example, some farmers may wish to return to traditional crops such as rice, as this is perceived as more individually profitable, yet adaptive methods such as shrimp farming are extremely profitable at the national level, even though the profits might be concentrated in the hands of a few people. Cost-benefit outcomes may therefore be favourable at national level but not for individual livelihoods.

A number of scalar variables present opportunities to frame more comparative inquiry in relation to the social construction of resilience. The extent to which interactions extend over geographic *space* is a variable relevant to climate change resilience, given the possibility of resilience to link actors together through boundary objects or infrastructures, and to manifest itself as a property across spaces. The *population* of actors involved in the construction of resilience may influence possible outcomes in terms of the emergence and/or maintenance of boundary organizations, infrastructures, objects etc. Different levels of human, social, environmental, financial and physical capital may also determine specific ways in which resilience is constructed. *Heterogeneity* can be evaluated in terms of the different social worlds actors may inhabit, or their capacities and status, which could include questions of inequality and exclusion. Finally, the *temporal* dimension of boundary practices is significant given the inevitable anticipatory orientation of climate change effects. Each of these variables could lend themselves to studies which compare the construction and mobilization of 'resilience' across different scales.

Table 1 demonstrates how each theme can be differentiated into a series of variables which could act as a template for research design. These themes and variables indicate how empirical studies can address the status of values, choices and pathways in framing resilience across the inevitably heterogeneous array of actors involved in responses to environmental change. The approach adopted here is intended to indicate a means of formulating research questions to address the relationship between representation and intervention, and to facilitate inquiry

concerning what kind of social impact resilience discourses exert. Such inquiries could critically assess the impact of specific socio-material mobilizations of resilience and identify potential pathways towards realizing possible alternatives.

Table 1. Summary of key themes and variables outlined in this section

Power and authority	Role of pre-existing authority (e.g. laws, enforceable regulations) in the negotiation of boundary objects
	Power relations as an outcome of boundary practices, including new laws or regulations
	Boundary practices leading to new interpretations of existing laws or regulations
	Presence/absence of sanctions/incentives shaping boundary practices
	Boundary practices leading to new sanctions/incentives
	Boundary practices leading to new interpretations of pre-existing sanctions/incentives
	Perceived power of boundary objects, infrastructures, organizations
	Socio-economic inequalities and the extent to which boundary practices overcome or perpetuate them
	Rules & procedures – formalized or tacit
Reflexivity	Intentionality
	Presence/absence of learning systems
	Awareness of incommensurabilities between actors
	Information asymmetries between actors engaged in boundary work
	Appeals to authority vs sense of individual agency
	Understandings of an actor's own interests
	Understandings of interests of others
Epistemological interactions	Differences between institutionalized ways of knowing
	Production of interdisciplinary knowledge
	Re-drawing of epistemic boundaries
	Degree and scale of internal heterogeneity within discipline (observed or perceived)
Scale	Population
	Spatial
	Temporal
	Degree of heterogeneity of actors

Conclusion

The possibility of resilience as a boundary object, as suggested by Brand and Jax (2007) has been acknowledged within subsequent literature (see for example Hutter et al 2013), but has seldom been pursued further. By taking up this challenge, this article has, through an examination of a wider array of literature, indicated that the boundary properties of resilience are more complex than first thought. Discourses of resilience both represent worlds and intervene in them. This article has considered how resilience may both shape boundary practices (boundary work, or the emergence of boundary objects, infrastructures or organizations), and may represent the outcome of such practices. A closer examination of the literature suggests a series of themes which indicate promising pathways to further explore the social boundary properties of resilience.

This article has sketched a framework which may assist researchers to traverse these pathways. This framework is intended to help move STS-influenced boundaries research on from the development of partially overlapping concepts. It is also intended to move resilience research beyond the definitional diversity of resilience, by drawing attention to how resilience acquires meanings in situated contexts, and the consequences of those meanings. While drawing upon STS to maintain an open-mindedness toward resilience discourses, this article seeks to move beyond existing boundaries research to address more directly matters of social justice, inequality and livelihoods in order to facilitate impactful research.

This article seeks to encourage systematic empirical comparison across cases, rather than conceptualizing resilience in abstract detail which risks limiting discussions to matters of definition. Subsequent research could point the way to identifying more clearly the challenges to transcending socio-cognitive boundaries in shaping thinking and cultures

regarding matters of environmental policy, and to understand more clearly what climate responses work and why.

A note of caution should however be added. Addressing resilience in such a way means that researchers should consider themselves to be potentially embedded in the same networks of articulation and mobilization that they seek to comprehend. Portrayals of these networks could themselves be construed as performative acts. The issue of reflexivity hence faces any such research. The factors outlined here however can be regarded as a guide for researchers to triangulate their position relative to a particular case of interest, and to spotlight any areas of power relation or incommensurability on the part of the researcher.

Rather than advocating a specific definition of resilience, this paper has sought to emphasise the performative aspects of resilience as a signifier. It advocates comprehensive understandings of how resilience discourses circulate among, and mobilize, complexes of people and things. This paper has sought to emphasise how resilience is something which may facilitate boundary practices, but which may also come about through boundary practices. It may involve the re-articulation of terms like loss and damage, and how they relate to socio-material interventions. The approach to resilience outlined here provides a means for researchers to trace links between diffuse and varied terms, practices and objects across spaces where framings of resilience emerge. The framework outlined in this paper is thus intended to suggest a way of making sense of what may seem an overwhelmingly complex series of landscapes.

References

Adger, W.N., K. Brown, D.R. Nelson, F. Berkes, H. Eakin, C. Folke, K. Galvin, et al. 2011. "Resilience Implications of Policy Responses to Climate Change." *Wiley Interdisciplinary Reviews: Climate Change* 2: 757–766.

Ayeb-Karlsson, S., T. Tanner, K. van der Geest and K. Warner (eds) (2015) *Livelihood Resilience in a Changing World: 6 Global Policy Recommendations for a More Sustainable Future*. UNU-EHS Working Paper Series No.22. United Nations University Institute of Environment and Human Security.

Bartel, C.A. 2001. "Social Comparisons in Boundary-Spanning Work: Effects of Community Outreach on Member's Organizational Identity and Identification." *Administrative Science Quarterly* 46(3): 379-413.

Bizikova, L., S. Tyler, M. Moench, M. Keller, and D. Echeverria 2015. "Climate Resilience and Food Security in Central America: A Practical Framework". *Climate and Development* 8(5): 397-412.

Bowker, G. and S.L. Star. 1999. *Sorting Things Out: Classification and its Consequences*. Cambridge, Mass: MIT Press.

Brand, F.S. and K. Jax. 2007. "Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object." *Ecology and Society* 12(1): 23-38.

Brown, K. 2014. "Global Environmental change I: A social turn for resilience?" *Progress in Human Geography* 38(1): 107-117.

Callon, M. 2007. "What Does it Mean to Say That Economics is Performative?" in MacKenzie, D., F. Muniesa, and L. Siu (eds), *Do Economists Make Markets? On the Performativity of Economics*. Princeton: Princeton University Press, 311-357.

Carlile, P. 2004. "Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries." *Organization science* 15(5): 555-568.

Cash, D.W. 2001. "In Order to Aid in Diffusing Useful and Practical Information:

Agricultural Extension and Boundary Organisations." *Science, Technology, and Human Values* 26(4): 431–453.

Clark, W.C., T.P. Tomich, M. van Noordwijk, D. Guston, D. Catacutan, N.M. Dickson and E. McNie. 2016. "Boundary Work for Sustainable Development: Natural Resource Management at the Consultative Group on International Agricultural Research (CGIAR)." *Proceedings of the National Academy of Sciences* 113(17): 4615-4.

Durkheim, E. 1892 [1982]. *The Rules of Sociological Method, and Selected Texts on Sociology and its Method*. London: Macmillan

Eden, S., A. Donaldson and G.P. Walker. 2006. "Green Groups and Grey Areas: Scientific Boundary Work, NGOs and Environmental Knowledge." *Environment and Planning A* 38(6): 1061-1076.

Edmond, G. 2000. "Judicial Representations of Scientific Evidence." *Modern Law Review* 63(2): 216-251.

Faulkner, A. and C. Lawless. 2012. *Material Worlds: Intersections of Law, Science, Technology and Society*. Oxford: Blackwell.

Fischer, G. 2001. "Communities of Interest: Learning through the Interaction of Multiple Knowledge Systems. Proceedings of the 24th Information research systems seminar in Scandinavia (IRIS) Conference, Bergen, Norway.

Flowminder (2014) http://www.flowminder.org accessed 23 September 2014.

Folke C., L. Pritchard, F. Berkes, J. Colding and U. Svedin. 2007. "The problem of Fit between Ecosystems and Institutions: Ten years Later." *Ecology and Society* 12(1): 30-67.

Franks, J. 2010. "Boundary Organizations for Sustainable Land Management: The Example of Dutch Environmental Co-operatives." *Ecological Economics* 70: 283-295.

Gillard, R. 2016 “Questioning the Diffusion of Resilience Discourses in the Pursuit of Transformational Change.” *Global Environmental Politics* 16(1): 13-20.

Gieryn, T. 1983. “Boundary Work and the Demarcation of Science from Non-science: Strains and Interests in Professional Ideologies of Scientists.” *American Sociological Review* 48(6): 781-795.

Gieryn, T. 1999. *Cultural Boundaries of Science: Credibility on the Line*. Chicago, Il: University of Chicago Press.

Goldberg, S. 1994. *Culture Clash: Law and Science in America*. New York: New York University Press.

Guston, D.H. 1999. “Stabilizing the Boundary between US Politics and Science: The Role of the Office of Technology Transfer as a Boundary Organization.” *Social Studies of Science* 29(1): 87-111.

Guston, D.H. 2001. Boundary Organizations in Environmental Policy and Science: An Introduction.” *Science, Technology and Human Values*. 26(4): 399-408.

Haas, P.M. (1992) “Introduction: Epistemic Communities and International Policy Coordination.” *International Organization*. 46(1): 1-35.

Hughes, T. 1983. *Networks of power: Electrification in Western society 1880-1930* Baltimore, MD: Johns Hopkins University Press.

Huq, S., E. Roberts and A. Fenton. 2013. “Loss and Damage.” *Nature Climate Change*. 3: 947-949.

Hutter, G., C. Kuhlicke, T. Glade and C. Felgentreff (2013) “Natural Hazards and Resilience: Exploring Institutional and Organizational Dimensions of Social Resilience.” *Natural Hazards*. 67: 1-6.

Irwin, A., H. Rothstein, S. Yearley and E. McCarthy. 1997. “Regulatory Science – Toward A Sociological Framework.” *Futures* 29(1): 17-31.

Jamieson, N.L. and G.W. Lovelace. 1985. “Cultural Values and Human Ecology: Some Initial Considerations.” *Cultural Values and Human Ecology in Southeast Asia* edited by Hutterer, K.L., A.T. Rambo and G.W, Lovelace, 27-54. Ann Arbor, Michigan, USA: Center for South and Southeast Asian Studies University of Michigan.

Jasanoff, S. 1987. “Contested Boundaries in Policy-Relevant Science.” *Social Studies of Science* 17: 195-230.

Jasanoff, S. 1990. *The Fifth Branch: Science Advisers as Policy Makers*, Cambridge, MA: Harvard University Press.

Jasanoff, S. 1993. “Bridging the Two Cultures of Risk Analysis.” *Risk Analysis* 13(2): 123-29.

Jasanoff, S. 2004. “Ordering Knowledge, Ordering Society” in *States of Knowledge: The Co-Production of Science and Social Order* edited by Jasanoff, S., 13-45. London: Routledge.

Kaufmann, A. and F. Todtling. 2001. “Science–Industry Interaction in the Process of Innovation: The Importance of Boundary-Crossing between Systems.” *Research Policy* 30(5): 791-804.

Keck, M. and P. Sakdapolrak. 2013. “What is Social Resilience? Lessons Learned and Ways Forward.” *Erdkunde*, 67(1): 5-19.

Knorr-Cetina, K. (1999) *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge, Mass: Harvard University Press.

Latour, B. (1987) *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, Mass: Harvard University Press.

Latour, B. 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, US: Harvard University Press.

Law, J. and Mol, A. 1995. "Notes on Materiality and Sociality". *The Sociological Review,* 43: 274-294.

Lawless, C.J. 2013. "The Low-Template DNA Profiling Controversy: Biolegality and Boundary Work Among Forensic Scientists". *Social Studies of Science* 43(2): 191-214.

Lorenzoni, I., M. Jones M. and J. Turnpenny. 2007. "Climate Change, Human Genetics, and Postnormality in the UK." *Futures* 39(1): 65–82.

Lynch, M and R. McNally. 2003. "Science', 'Common sense' and DNA Evidence: A Legal Controversy about the Public Understanding of Science." *Public Understanding of Science* 12: 83-103.

McSweeney, K., E.A. Nielsen, M.J. Taylor, D. Wrathall, Z. Pearson, O. Wang O and S.T. Plumb. 2014. "Drug Policy as Conservation Policy: Narco-deforestation." *Science* 343(6170): 489-490.

Mayunga, J.S. 2007. Understanding and Applying the Concept of Community Disaster Resilience: A Capital-Based Approach". Draft working paper prepared for the summer academy, "Megacities as Hotspots of Risk: Social Vulnerability and Resilience Building." Munich, Germany, 22–28 July 2007

Miller, C. 2004. "Climate Science and the Making of a Global Political Order." in *States of Knowledge: The Co-Production of Science and Social Order,* edited by Jasanoff, S., 46-66. Routledge, London.

Moore, K. 1996. "Organizing Integrity: American Science and the Creation of Public Interest Organizations." *American Journal of Sociology* 101(6): 1592–1627.

Morrissey, J. and A. Oliver-Smith. 2013. “Perspectives on Non-Economic Loss and Damage: Understanding the Value at Risk from Climate Change’, http://www.lossanddamage.net/download/7213.pdf Accessed 7 November 2014.

Park, J. 2010. *Boundary Infrastructures for IBIS Federation: Design Rationale, Implementation, and Evaluation*. Thesis Proposal, available as: Technical Report KMI-10-01, Knowledge Media Institute, The Open University, UK. http://kmi.open.ac.uk/publications/pdf/kmi-10-01.pdf accessed 23 September 2014

Pinch, T. and R. Swedberg. 2008. *Living in a Material World: Economic Sociology meets Science and Technology Studies*. Cambridge, Mass: MIT Press.

Schuck, P.H. 1993. “Multi-Culturalism Redux: Science, Law, Politics.” *Yale Law and Policy Review*. 11(1): 1-46.

Sovacool, B.K. and B. Brossman. 2013. “Fantastic Futures and Three American Energy Transitions.” *Science as Culture* 22(2): 204-212.

Star, S.L. and R. Griesemer. 1989. “Institutional Ecology, ‘Translations’ and Boundary Objects: Amateurs and Professionals in Berkeley’s Museum of Vertebrate Zoology, 1907-39.” *Social Studies of Science*. 19(3): 387-420.

Star, S.L. and K. Ruhleder. 1996. “Steps Towards an Ecology of Infrastructure: Design and Access for Large Information Spaces.” *Information Systems Research* 7(1): 111-134.3

Tàbara, J.D. 2013. “Social Learning to Cope with Global Environmental Change and Unsustainability” in: *The Routledge International Handbook of Social and Environmental Change. London and New York* edited by Lockie, S., D.A. Sonnenfeld, and D.R. Fisher. London, New York: Routledge, 253-265.

Tanner, T., D. Lewis, D. Wrathall, R. Bronen, N. Cradock-Henry, S. Huq, C. Lawless. et al 2015. “Livelihood Resilience in the Face of Climate Change.” *Nature Climate Change*, 5: 23-26.

Trompette, P. and D. Vinck. 2009. “Revisiting the Notion of Boundary Object.” *Revue D'anthropologie des Connaissances.* 3(1): 3-25.

Warner, K., K. van der Geest and S. Kreft. 2013. *Pushed to the Limit: Evidence of Climate Change-Related Loss and Damage when People face Constraints and Limits to Adaptation.* Bonn: United Nations University Institute for Environment and Human Security Report No.11.

Weichselgartner, J and I. Kelman. 2015. “Geographies of Resilience: Challenges and Opportunities of a Descriptive Concept.” *Progress in Human Geography*. 39(3): 249-267.

Welsh, M. 2014. “Resilience and Responsibility: Governing Uncertainty in a Complex World.” *The Geographical Journal*. 180(1): 15-26.

Wynne, B. 1996. “May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide.” In *Risk Environment and Modernity: Towards a New Ecology* edited by Lash, S., B. Szerszynski and B. Wynne, 44-83. London: Sage Publications.