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How do we know about resilience? An analysis of empirical research on resilience, and implications for interdisciplinary praxis

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Abstract
We sought to understand how knowledge about resilience is produced. We examined empirical research into resilience from the social and natural sciences, randomly selected a sample of these studies and analysed their methods using common criteria to enable comparison. We found that studies of resilience from social scientists largely focus on the response of individuals to human-induced change events, while those from natural scientists largely focus on the response of ecological communities and populations to both environmental and human-induced change events. Most studies were of change over short time periods and focused on small spatial scales. Social science studies were dominated by one-off surveys, whereas natural science studies used a diversity of study designs to draw inferences about cause-and-effect. Whilst these differences typically reflect epistemological and methodological traditions, they also imply quite different understandings of resilience. We suggest that there are significant methodological barriers to producing empirical evidence about interactions between complex social and ecological systems.

Keywords: social science, ecological science, methodology, evidence, study design

1. Introduction

Interest in the concept of resilience comes from a wide spectrum of disciplines across the social and natural sciences. The concept of resilience is used to analyse responses to change in human and natural systems over various spatial and temporal scales. There is an established body of work on the concept of resilience within the social sciences, such as psychology, and the natural sciences, notably ecology, as well as an emerging field of interdisciplinary studies on the resilience of integrated social–ecological systems. The breadth of interest in resilience means there is considerable variation in the ways in which resilience is understood, investigated and applied. We seek here to explore this variation.

There has been a great deal of review of the concept of resilience and its meaning, applications, and functions (Folke 2006, Gunderson 2000, Handmer and Dovers 1996, Lorenz 2010, Manyena 2006, Walker and Cooper 2011). Resilience, we now know, has no agreed definition and is many things, including: a descriptive and normative concept; a way of thinking; an approach to research on social,

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Table 1. Examples of definitions of the term 'resilience' that underpinned examination of the resilience literature in the ecological and social sciences.

Definition	Source
'Capacity of a system to absorb and recover from the occurrence of a hazardous event' (p 21)	Timmerman (1981)
'The measurement of resilience is the magnitude of disturbance that can be absorbed or accommodated before the system changes its structure by changing the variables and processes that control system behavior' (p 330)	Holling and Meffe (1996)
'How a system copes with major perturbations to its operating environment' (p 486)	Handmer and Dovers (1996)
'Conditions in which disturbances (or perturbations) can flip a system from one equilibrium state to another. . . . the important measure of resilience is the magnitude or scale of *disturbance that can be absorbed* before the system changes in structure by the change of variables and processes that control system behaviour' (p 12, emphasis in original)	Berkes and Folke (1998)
Defines social resilience as 'the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change' (p 347)	Adger (2000)
'Ecological resilience refers to the width or limit of a stability domain and is defined by the magnitude of disturbance that a system can absorb before it changes stable states' (p 427)	Gunderson (2000)
'Resilience refers to a *dynamic process encompassing positive adaptation within the context of significant adversity*' (p 543, emphasis in original)	Luthar *et al* (2000)
'The amount of disturbance a system can absorb and still remain within the same state or domain of attraction; the degree to which the system is capable of self organisation' (p 43)	Klein *et al* (2003)
'The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure this is determined by the degree to which the social system is capable of organising itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures'	UN ISDR (2005)
'Disaster resilience could be viewed as the intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its non-essential attributes and rebuilding itself' (p 446)	Manyena (2006)
In human developmental science 'individual resilience refers to the processes of, capacity for, or patterns of positive adaptation during or following exposure to adverse experiences that have the potential to disrupt or destroy the successful functioning or development of the person' (p 10)	Masten and Obradovic (2008)
'Social resilience is defined as the social system property of avoiding or withstanding disasters' (p P1)	Lorenz (2010)

ecological, and social–ecological systems; a framework; and a boundary object (Adger 2000, Brand and Jax 2007, Folke *et al* 2010, Gunderson 2000, Nelson *et al* 2007). It is not within the scope of this paper to provide a review of the diverse definitions of resilience; comprehensive reviews of the meaning of resilience, disciplinary origins and characteristics are provided by Brand and Jax (2007) and Manyena (2006). A selection of definitions, as provided in table 1, reveals the breadth of definitions adopted across the ecological and social sciences. The only constant in all these (and other) definitions is a concern with the response to undesirable changes. It is this concern for response to change that enables the concept to be meaningfully applied in the fields of natural resources management and conservation (Berkes and Folke 1998, Berkes *et al* 2002, Holling and Meffe 1996, Gunderson 2000), disaster management (Klein *et al* 2003, Manyena 2006, UN ISDR 2005), climate change adaptation (Galliard 2010, Timmerman 1981) as well as psychology and human development (Luthar *et al* 2000, Masten and Obradovic 2008). More recently the concept has been applied in studies of financial management, urban planning and environmental security (Walker and Cooper 2011). By using definitions springing from the ecological and social sciences, we make no judgements about the merits of empirical research in these respective fields, nor should our analysis be taken to imply that there should be some convergence between fields. Rather, we simply aim to describe the differences in approaches.

In amidst all these meanings and applications we ask—how it is that we know about resilience? What common features exist in the way resilience is studied across the disciplinary spectrum? We seek to answer these questions through a systematic and comparative analysis of the methodologies used in empirical studies informed by the concept of resilience, and/or which seek to understand resilience as a phenomenon. We examine and contrast the entities studied, the sources of change events, temporal and spatial scales of studies and, most importantly, the study design that underpinned inference of cause-and-effect. The approach is unique, for while there are many reviews of the definitions of resilience within and between fields of study (e.g. Gunderson 2000, Lorenz 2010, Manyena 2006, Miller *et al* 2010, Nelson *et al* 2007, Turner 2010), and

which explain the genealogy of the concept (e.g. Folke 2006)—and even studies of the networks of researchers that study resilience (e.g. Janssen *et al* 2006; Janssen 2007)—there is to our knowledge no study that reviews how knowledge about resilience is generated (in this case through empirical research). We are particularly interested in what is happening at the poles of this spectrum, notably within the social sciences and the natural sciences. We do not focus on studies of social–ecological systems because these papers are likely to reflect a mix of approaches. Instead, our aim is to highlight research on resilience that may be less well known to readers interested in changes in social–ecological systems—that is research from the social sciences on phenomena that are not necessarily (indeed rarely) 'environmental', and research from the natural sciences that is far less concerned with coupled social–ecological systems. In this way we hope to convey a better sense of what gets done at the ends of the spectrum of research on resilience, in order to generate insights that might enhance understanding of challenges of interdisciplinary research on resilience.

How we know about resilience is important because if research on resilience is to inform practice in some way, then that research needs to be robust, and at least to some degree evidence based (Thrush *et al* 2009, Vogel *et al* 2007). Clarity on the methodologies applied allows for the rigour of this evidence to be evaluated and permits studies to be comparable across time and space—a necessary component of theory development. Clarity on methodologies applied within and across the social and natural sciences is also critical to fostering fruitful interdisciplinary collaboration and improving the capacity of different fields to learn from each other. Thus, the ways in which evidence about resilience is produced is important. We designed a systematic approach to assessing the way evidence about resilience is produced, which we now explain.

2. Methods

2.1. Data collection

Data were retrieved from the Institute of Scientific Information's (ISI) *Web of Science* between March and November 2010. The *Social Sciences Citation Index* and the *Arts and Humanities Citation Index* were used to identify the 'social science papers' and the *Science Citation Index Expanded* was used to identify the 'ecological papers'.

2.2. Key word search

A key word search using the term 'resilien*' to search the title, keywords and abstract entries was employed. It excluded 'book reviews' in the case of the social science papers and was limited to 'articles' in the case of the ecological papers. The time span for the papers in the search was not limited.

2.3. Subject areas

The data were then refined according to subject area. In the case of the social science papers, papers in the subject areas deemed peripheral to the social science focus or that were known to be included in the ecology search were excluded. The search of the social science papers included those with the following subject areas (the following list is those fields that returned more than 10 papers in this initial search): Anthropology or Archaeology or Area Studies or Behavioural Sciences or Business (and Finance) or Communication or Criminology and Penology or Demography or Economics or Education (and Education and Special) or Environmental Studies or Ethics or Ethnic Studies or Family Studies or Industrial Relations and Labour International Relations or Geography or Gerontology or History or History and Philosophy of Science or Humanities or Philosophy or Planning and Development or Law or Management or Political Science or Psychiatry or Psychology (Applied and Developmental and Educational and Multidisciplinary and Social) or Public Administration or Public Health or Social Issues or Social Sciences (Biomedical and Interdisciplinary) or Social Work or Urban Studies or Women's Studies.

The search of the ecological papers included those papers with the following subject areas: Ecology or Environmental Studies or Environmental Sciences or Marine and Freshwater Biology or Limnology or Zoology or Water Resources or Forestry or Plant Sciences or Mathematical and Computational Biology or Oceanography or Toxicology or Soil Science or Evolutionary Biology or Fisheries or Biodiversity Conservation or Biology or Soil Science or Urban Studies or Entomology or Parasitology or Palaeontology.

2.4. Random selection of sample data

Data sets from the social science and the ecological searches were compared, removing duplicates. Following this process, some 3759 social science entries and 2789 ecological entries formed our population data.

A pilot study of a sample of papers was undertaken by all the authors to review the range and type of papers to determine appropriate categories for analysis.

A random selection of the total social and ecological data sets (using *Excel* random selection formulae) was generated, resulting in a sample of 337 papers.

2.5. Data cleaning

Of these 337 papers, 18 social and 116 ecological papers were excluded because they were not relevant (i.e., they were not actually about resilience), based on the expert judgements of the authors Ellemor and Glaister. A further seven were excluded because they were written in a language other than English, leaving 106 and 91 social and ecological studies, respectively.

2.6. Inclusion of empirical studies only

Only empirical papers were included in our study, as we were interested to discern the empirical foundations for theories of resilience, and to see, in turn, if resilience is a concept that gives rise to empirical investigation. The test of empirical

Table 2. Explanation of the categories of study designs (which were the same in both social science and ecological studies) and the categories of temporal and spatial scales, which differed in interpretation between social science and ecological studies.

Characteristic	Names of types	Explanation	
Study design	Areal	A study done across space along a gradient of effect of a change event	
	Temporal	A study done over time to examine slow and incremental change	
	Before/after	A study before and after an identifiable discrete change event	
	Experiment	An experimental manipulation	
	One-off survey	A survey that is independent of a particular event that seeks to understand attributes of a particular entity	
		Social sciences	*Ecological*
Entities of study	Individuals	Individual people in a society	Individuals of a species
	Families	Families	—
	Populations	—	Populations of species
	Communities	Communities or social groups	Ecological communities (habitat- or taxon-based species groups)
	Social sectors	Social sectors	—
	Ecosystems	—	Whole ecosystems
Temporal scales	Short	0–4 years	<1 year
	Medium	5–24 years	~2–10 years
	Long	25+ years	Multiple decades
Spatial scales	Local	Socially local	Ecologically local
	Regional	Within a country	Within a biophysical region type
	National	Within a nation	—
	Continental	—	Across a whole continent
	International	Between nations	—
	Global	—	Across the entire globe

applied here is if a publication both explains its method and presents primary data. Of the 106 and 91 social and ecological papers, a further 27 social and 15 ecological papers were excluded because they did not contain any original data, leaving a sample of 79 and 76 social and ecological papers, respectively. Finally, another 6 papers were excluded from the social set because closer examination showed that they investigated social–ecological systems (i.e., sat at the intersections of ecological and social research rather than being clearly in one discipline or the other).

2.7. Data limitations

The data set, though randomly generated, only contains those articles that appear in the ISI databases. It is primarily limited by the fact that it does not contain books and book chapters. It also excludes non-English language papers.

2.8. Data analysis

Each journal article was read by one of the five authors. Codes were allocated to answer 15 questions, the most pertinent of which queried the sources of change events (e.g. human or ecological), the temporal and spatial scales of studies, and study design (table 2). Equivalent, though not always the same, codes/categories were used for each data set. Basic statistical analysis of the data using contingency tables and χ^2 with α set to 0.05 (Sokal and Rohlf 1995) was undertaken to explore prospective differences between ecological and social studies, which we now discuss.

3. Results

3.1. Entities and change events studied

Comparisons between the two sets of studies revealed some marked differences in the way resilience is studied. Social science studies were overwhelmingly focused on individuals whereas ecological research focused more on ecological populations and communities (table 3) and this difference in the dominant entities of study was statistically significant. Social studies focused almost entirely on human sources of change events (such as economic and political change, sources of stress such as illness or family violence) (table 3(b)). In contrast, both human (e.g. climate change) and ecological change (e.g. hurricane, drought) events were well represented in ecological research (table 3(b)), and this difference between ecological and social studies was also statistically significant (table 3(b)).

3.2. Defining resilience

Few ecological studies (21%) defined resilience or provided a reference to the meaning of the word, whereas 40.5% of social science studies provided a definition, a difference between social and ecological studies that is once again statistically significant ($\chi^2 = 6.2$, $P = 0.013$).

3.3. Scales of analysis

The temporal and spatial scales over which studies were carried out differed between social science and ecological

Table 3. Data on (a) the entities examined and (b) sources of change events in 76 ecological and 73 social science studies of resilience. Given are the numbers of studies in different categories, the percentages of studies, and the χ^2 and *P*-value for testing whether the percentages of studies in difference categories (entities examined, sources of change events) varied between ecological and social studies. For the purposes of analysis, ecosystems and social sectors were considered analogous entities, as were populations and families given they were intermediate between individuals and communities but we are not implying that categories should be considered to be directly comparable.

	Number of studies	%	χ^2	*P*
(a) Entities examined				
Social science studies				
Individuals	55	75.3		
Families	7	9.6		
Communities	6	8.2		
Social sectors	5	6.8	70.0	<0.001
Ecological studies				
Individuals	7	9.2		
Populations	17	22.3		
Communities	42	55.3		
Ecosystems	10	13.2		
(b) Sources of change events				
Social science studies				
Human	71	97.3		
Ecological	2	2.7	29.8	< 0.001
Ecological studies				
Human	46	60.5		
Ecological	30	39.5		

research. Unsurprisingly, studies over short time periods were the most common overall but ecological studies comprised many more long term studies than found in the social sciences (table 4(a)). Similarly, both research fields were dominated by work done at small spatial scales (local scales) but particularly so in ecological research, whereas in the social sciences studies at a national level were almost as common as locally based research (table 4(b)). Global-scale and international studies were uncommon.

3.4. Study design

Perhaps the most interesting results lie in the comparison of research designs used in the social and ecological studies, and their means of inference about cause-and-effect. Social science research was dominated by one-off, explorative surveys that investigated attributes of entities (table 4(c)). There were a few studies of entities over time, but before/after research around a particular change event was uncommon. Unsurprisingly given ethical considerations, experiments were unusual in social science research but there were also no examples in our sample of research done over spatial gradients of a change event (table 4(c)). In contrast, ecological research was spread much more evenly across types of study designs, with one-off surveys comprising the least common study type.

4. Conclusion

4.1. Systems thinking

Whilst there are diverse definitions of resilience, one of the common features of most definitions is that the concept refers to how a *system* experiences and responds to *change* (Manyena 2006, Thrush *et al* 2009, and table 1). Our analysis of the studies reviewed indicate that understanding of how systems respond to change is limited by an overwhelming focus at the level of individual (social studies) or population and community (ecological studies). For the latter, a focus on communities is somewhat understandable given that testing hypotheses on entire ecosystems is logistically difficult (Thrush *et al* 2009). Nevertheless, we found it surprising that the number of studies on resilience that put results into an ecosystem context were few. Systems, whether understood in a social sense (in terms of the structure and function of relationships at a family, neighbourhood, workplace or community) or in an ecological sense (i.e. at an ecosystem level), do not form a large proportion of our sample, although more so for the ecological than social papers. Consequently resilience research that can address questions about systems are a lot less common than the literature about resilience assumes. Masten and Obradovic (2008) also note that in human development research on resilience there is little research connecting individual resilience to larger social systems.

4.2. Snapshot understanding of change

A key insight generated by resilience research concerns the largely unpredictable and non-linear nature of change (Holling 1996, Manyena 2006, Masten and Obradovic 2008). Yet, one of the disturbing findings of our review is that the majority of studies in our sample consider very short temporal scales of change. Whilst a larger proportion of the ecological studies are undertaken over a longer period, the limited temporal scale considered in the studies overall potentially restricts the extent to which system processes and responses

Table 4. Categorization of research (numbers of studies and percentages) according to (a) length of time periods of studies, (b) spatial scales of studies and (c) study designs together with the outcomes of tests (χ^2 values and associated probabilities, P) of whether frequencies of study types differ between social science and ecological studies of resilience. Explanation of temporal and spatial scales and study designs is given in table 1.

	Social science	Ecological	χ^2	P
(a) Time periods				
Short	51 69.9%	44 57.9%	7.60	0.02
Medium	19 26.0%	18 23.7%		
Long	3 4.1%	14 18.4%		
(b) Spatial scales				
Local	34 46.6%	59 77.6%	21.1	<0.001
Regional	16 21.9%	12 15.8%		
National/continental	19 26.0%	2 2.6%		
Global	4 5.5%	3 3.9%		
(c) Study designs				
Areal	0 0.0%	15 19.7%	81.30	<0.001
Temporal	9 12.3%	15 19.7%		
Before/after	5 6.8%	23 30.3%		
Experiment	1 1.4%	16 21.1%		
One-off survey	58 79.5%	7 9.2%		

to change events can be understood. For instance, delayed responses to change, and the synergistic and cumulative interaction of multiple change events may not be captured within such studies. There is also a critical time element in the way in which social systems response to change in terms of how people and institutions anticipate and prepare for change, recover and learn, which influence resilience. These are important temporal dimensions of change that are theorized about in the resilience literature, yet our study concludes that the empirical body of work on this dimension is limited.

4.3. Capturing cross-scale interactions

The spatial scale of analysis is significant in determining the extent to which relevant processes of change and response are identified and explained, and indeed, scale and cross-scale dynamics are key concerns within resilience (see Berkes *et al* 2002, Cumming *et al* 2006, Peterson *et al* 1998). The overwhelmingly local spatial focus of the studies reviewed, particularly for the ecological studies, limits the consideration of wider scale processes. While local studies may consider the broader, spatial context in which they sit, this is not equivalent to capturing data over large spatial scales, which can provide definitive information about when and how findings at small scales can be (if ever) scaled up or applied to other seemingly, similar locations.

4.4. Favoured methods

There is more diversity in the methods applied to study resilience in the ecological studies we reviewed compared with the social science work, which largely draws upon one-off, explorative surveys. There are surprisingly few 'before/after' studies undertaken in the social sciences, which may reflect the way in which resilience is most often interpreted in the reviewed papers as a condition (rather than an outcome) and distinct from particular change events, in contrast to interpretations in the ecological sciences that focus

on how entities respond to change over time. Nevertheless, the predominance of one-off surveys in social studies of resilience may signal that the benefits of using study designs that can provide greater inferential capacity have not been fully appreciated. Before/after studies or those designed to take advantage of spatial or temporal gradients in a change event can provide much more direct tests of hypotheses of cause-and-effect than open-ended, explorative surveys (Downes *et al* 2002).

4.5. Implications for interdisciplinary research on resilience

It is often said that research on resilience should seek to enhance understanding of the interactions between social and ecological systems across a range of spatial and temporal scales (Leslie and McLeod 2007, Armitage *et al* 2009, Fischer *et al* 2009, Chapin *et al* 2010, Polasky *et al* 2011). Many studies emphasize the importance of having multidisciplinary teams in which ecological and social scientists work together to improve conservation of ecosystems and the protection of the societies dependent upon them. Increasingly there is a recognition amongst resilience scholars of the need for trans-disciplinary approaches to research (Miller *et al* 2008, Vogel *et al* 2007), that rethink not only disciplinary boundaries but also the research–policy–practice interface. The success of such approaches depend on there being not only a recognition of the great diversity in meanings of words such as 'resilience' but also the considerable difference in understandings of the characteristics of resilient systems and the evidence upon which such understandings are based. Our research suggests that such approaches may suffer difficulties in realizing a robust understanding of what factors confer resilience upon systems, unless this diversity in the types of evidence available in the social and ecological literatures is recognized, appreciated and reconciled. Consequently, such approaches will need to devote considerable time and effort to building such an appreciation and reconciliation, but highly beneficial, new research directions and approaches are likely to result. It is suggested that future research needs to give greater attention to capturing cross-scale processes and change in systems over time, using research designs that are to some degree common with respect to spatial and temporal scale and methods for collecting evidence about cause-and-effect.

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