GROUP OF SOCIAL STUDIES - HUMAN DIMENSION
CENTER FOR CLIMATE AND RESILIENCE RESEARCH - CR2
WORKING PAPER

2014

RESILIENCE IN THE CONTEXT OF CLIMATE CHANGE: A SYSTEMATIC REVIEW OF THE LITERATURE TO AID A NAVIGATION OF DIVERSITY

Aldunce, P.[1,2], Indvik, K.[1], Borquez, R.[1], Adler, C.[3], Galaz, V.[4]

(1) Center for Climate and Resilience Research, Blanco Encalada 2002, Santiago, Chile; (2) Universidad de Chile, Facultad de Ciencias Agronómicas, Departamento de Ciencias Ambientales y Recursos Naturales, Av, Sta Rosa 11315, Santiago, Chile; (3) ETH Zürich, Institute for Environmental Decisions, Universitätstrasse 22, 8092 Zürich, Switzerland; (4) Stockholm University, Stockholm Resilience Centre, Kräftriket 2B, Stockholm, Sweden.

Corresponding author: Paulina Aldunce (paldunce@uchile.cl)

Abstract

Resilience in the context of climate change has rapidly gained popularity within scientific literature across a wide array of disciplines. With an increasing richness and diversity of perspectives, discussion also arises regarding the ambiguity of resilience definitions and conceptualizations. Ambiguity has the potential to distract and even paralyze researchers and practitioners in their efforts to operationalize initiatives responding to a changing climate. Structuring an understanding of the richness embedded in the diverse resilience definitions and features is necessary to support problem-framing and knowledge interpretation and application.

This study aims to structure, clarify, and analyze the broad range of existing definitions stemming from multiple epistemologies and disciplinary approaches, in order to aid navigation of this diversity and to contribute to resilience theory and its practical operationalization. Literature published from 2000 to 2012 was systematically selected and reviewed for relevance to resilience in a climate change-specific context. Observed definitions of resilience were broadly categorized as: social, ecological, social-ecological and structural/physical resilience, with a majority referring to social or social-ecological resilience. Results demonstrate that over 90% of resilience definitions define ability or capacity, most commonly to absorb, adapt, recover, or maintain. The study also identifies the conceptual basis of resilience theory that permeate climate change literature; theoretical assumptions related to ideas of change, systems and their complexities and interactions, uncertainty, and considerations of scale (both spatial and temporal) were frequently observed. Key determinants, attributes, and indicators that can be used to assist resilience building were also identified, and we propose a ´Resilience Wheel´ to present these results and guiding principles for climate change resilience building and assessment. This study represents an important contribution to resilience conceptualization within a specifically climate change context.

Keywords: Resilience, climate change, systematic review, Resilience Wheel, building, assessment

1. Introduction

Resilience as a concept is gaining considerable attention in the climate change literature, yet the way in which the term is framed and conceptualized varies significantly across fields and disciplines, in both academia and practice. Understanding how resilience is diversely conceptualized is essential to pragmatically managing and making the most of this diversity. The roots and development of resilience as a theory, and therefore of the term itself, are contested (Bodin and Wiman, 2004; Moser, 2008). Some authors argue that resilience was first developed in mathematics and physics and emerged in ancient thinking (Bodin and Wiman, 2004; Van der Leeuw and Leygonie, 2000). Others suggest that resilience theory derives from psychology and psychiatry and that it can be traced to the work of Garmezy, Werner and Smith in the 1940s (Johnson and Wiechelt, 2004; Waller, 2001). Alternatively, resilience theory has been applied and developed within ecology, initially by Holling (1961), Lewontin (1969), May (1972), and Rosenzweig (1971).

In mathematics and physics, resilience refers to the ability of a material to return to equilibrium without breaking or becoming deformed (i.e., the dynamic behavior of a system), and the speed with which this return occurs after a displacement (Bodin and Wiman, 2004; Gordon, 1978; Norris et al., 2008). In ecological literature, this type of resilience is described as 'engineering resilience' and "focuses on behavior near stable equilibrium and the rate at which a system approaches steady state following a perturbation, i.e. the speed of return to equilibrium" (Folke, 2006:256).

Within the disciplines of psychology and psychiatry, resilience was first applied to the study of individuals and later expanded to the study of human communities and large societies (Norris et al., 2008). This evolution has contributed to the application of resilience ideas to other disciplines and fields within the social sciences and has led, for example, to the conceptualization of what is now known as community and social resilience. Within the social sciences, resilience primarily refers to the capacity of individuals, communities and social groups to preserve function, respond, withstand and recover from a misfortune, trauma or stress (Adger, 2000; Norris et al., 2008; Pfefferbaum et al., 2005). Some authors complement this definition by stating that resilience includes adaptation (Egeland et al., 1993; Masten et al., 1990) and the strengthening of community (Chenoweth and Stehlik, 2001) and of social capital (Norris et al., 2008).

Holling's (1973) seminal paper "Resilience and stability of ecological systems" is often described as the starting point of 'resilience thinking'. Holling describes ecological resilience as buffering capacity and as an ability to persist and absorb perturbation, as the magnitude of disturbance a system can absorb before changing its structure and variables, and as the recovery time needed to do so (Holling, 1973; Holling et al., 1995). The notion of resisting or withstanding shocks has evolved to incorporate a capacity for continuous development, adaptation, and transformation, and the degree to which systems have or can build capacity for self-organization, learning, changing, and renewal within a dynamic environment (Adger et al., 2005; Anderies et al., 2013; Gunderson and Folke, 2005; Liu et al., 2007; Resilience Alliance, 2012).

The idea of ‘system’ (Holling, 1973; Holling et al., 1995) has been fundamental to this conceptualization and has since evolved to include complex adaptive systems and linked Social-Ecological Systems (SES), where social and ecological systems interplay over varying spatial and temporal scales (Adger et al., 2005; Gunderson and Folke, 2005). SES literature also describes resilience as “ the tendency of a SES subject to change to remain within a stability domain, continually changing and adapting yet remaining within critical thresholds” (Folke et al., 2010) and as “the ability of socio-ecological systems (SES) to absorb disturbance without flipping into another state or phase” (Cote and Nightingale, 2012). Within these systems, central features of resilience include the diversity and redundancy of various components, as well as the individuality and uniqueness of these components (Folke et al., 2005). Uncertainty is considered inevitable within complex adaptive systems; there is, therefore, a need to learn to live with this uncertainty (Berkes, 2007; Folke, 2006).

Irrespective of the origins of resilience theory, the resilience approach has been applied broadly, influencing research across numerous disciplines, and has been included in various guiding documents, policies and programs from a local to international level (Bahadur et al., 2010; DFID2009; Vogel et al., 2007; Walker and Salt, 2006). This wide-ranging and diverse use of resilience has led to the proliferation of multiple definitions of the concept, and it is acknowledged within resilience literature that this has the potential to create confusion within the academic community, amongst policy makers and practitioners, and between related fields (Brown and Westaway, 2011; Buckle, 2006; Cutter et al., 2008; Djalante and Thomalla, 2011; Gaillard, 2010; Godschalk, 2003; Klein et al., 2003a; Moser, 2008). As in other fields, resilience ideas have been applied increasingly to climate change, both within academia and in practice, and an expanding application has led to an increased wealth and diversity, but also inevitably dispersion, of ideas (Aldunce et al., 2015; Bahadur et al., 2010; Brown, 2013; Norris et al., 2009).

In the search for clarification, several studies have been conducted to analyze resilience definitions (Aldunce et al., 2015; Manyena, 2006; Norris et al., 2008) but few of these studies have focused on a specifically climate change context (Bahadur et al., 2010). These studies have been useful in clarifying the use of resilience; nevertheless, at time of publication, none of these studies compromise a systematic review of resilience conceptualizations within specifically climate change literature spanning such an extensive period of time (2000-2012). This is important because an understanding of the convergences and divergences of diverse definitions of resilience can affect the way the term is framed and used by scientists and practitioners (Downes et al., 2013a).

The recent proliferation of climate change resilience literature necessitates systematic methodology for its review, in order to structure and facilitate interpretation and application. The aim of this study is three-fold: to deconstruct resilience by systematically collecting, analyzing, and consolidating the broad range of existing resilience definitions and uses as applied specifically to climate change, and to propose a resilience conceptualization specifically applied to climate change as a starting point for resilience assessment and operationalization; to examine the context of theoretical assumptions in which resilience is constructed; and to propose principles that can guide resilience building and assessment by means of the systematic identification of resilience determinants, the attributes of these determinants, and potential indicators for these attributes.

2. Methods

This study consisted of systematic retrieval, review, selection and analysis of documents using carefully and explicitly established criteria (Berrang-Ford et al., 2011). This method allows for the summarization and evaluation of existing knowledge of a given topic (Berrang-Ford et al., 2011; Ford et al., 2011).

Documents included in this literature review were selected from results returned by a search of the SciVerse Scopus Database. Figure 1 illustrates the process of document selection and revision.

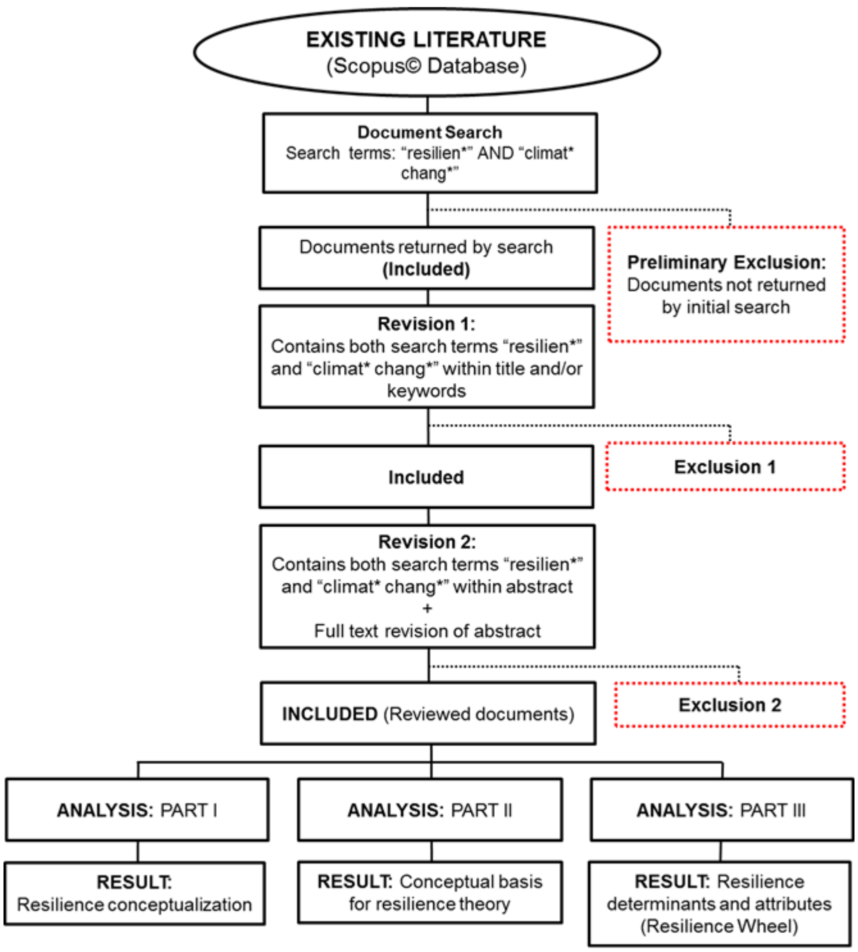

Figure 1. Document selection process

2.1. Document selection

2.1.1. Initial literature search procedure and parameters

A document search was executed within the Scopus SciVerse Database (©2013 Elsevier Properties B.V.) for the search terms “resilien*” AND “climat* chang*”, within document title, abstract and/or keywords (“Article Title, Abstract, Keywords” search option in Scopus) (Table 1).

Table 1. Search terms and possible (included) variations

Search term:	Included variations:
Resilien*	Resilience(s); Resilient; Resiliency/Resiliencies
Climat* Chang*	Climate Change(s); Climatic Change(s)

The document search was limited to articles and reviews published from 2000 to 2012, 2000 corresponding to the literature cutoff for the IPCC´s Climate Change 2001: Synthesis Report (Watson and Albritton, 2001), and 2012 representing the last complete year of literature available at time of analysis. Scopus was selected for its size, relatively balanced geographical distribution and social-to-biophysical science literature distribution, as well as for its indexing and search options (Jacso, 2005). Documents in English from all subject areas were included. All document titles, abstracts, keywords and bibliographic information were exported from Scopus to EndNote X6 (©1996-2012 Thomson Reuters).

2.1.2. Document review and exclusion criteria

Article abstracts were reviewed and included or excluded based on two-part criteria. Initial exclusion was based on title and keyword content (Revision 1, Figure 1). Included documents contained both search terms “resilien*” and “climat* chang*” at least once, within either title or keywords. This exclusion aimed to select those documents with the most substantial focus on resilience and climate change (and those documents not providing keywords were automatically included for additional review).

Document abstracts were subsequently reviewed for the appearance of search terms (Revision 2, Figure 1), and only those documents with both terms appearing in the abstract were included. Finally, the full text of each abstract was read and analyzed to determine whether or not resilience to climate change was integral to a given study. Documents were excluded, included, or labeled as ambiguous. Ambiguous documents were reviewed by and discussed with other team members in order to reach consensus on inclusion or exclusion; when necessary, full texts were examined to determine relevance.

Full abstract and full text review was performed independently by researchers for a random sample of documents in order to compare results and verify the effectiveness and validity of these exclusions.

2.2. Analysis

The full text and bibliographical information for all selected documents was imported into the software NVivo 10 (©QSR International 2012). Codes were created within the program in order to conduct a thematic analysis by identifying emerging patterns. Coding accuracy and consistency between (three) researchers was compared and confirmed. Analysis was divided in three main components as detailed below, in order to propose a conceptualization for resilience building and assessment, including a definition of resilience, theoretical assumptions, and key determinants.

2.2.1. PART I: Deconstruction of resilience definition and concepts

In order to better analyze observed definitions of resilience as applied within various disciplines and to distinct contexts, we organized definitions into four main types of resilience: social, ecological, social-ecological and structural/physical resilience. Three of these divisions were derived from the origins of resilience theory (in physical, social, and ecological sciences); the fourth – social-ecological – was included as a reflection of observed and documented trends towards its inclusion in the literature.

Content collected using NVivo and providing definitions for each type of resilience was analyzed. Analysis consisted of systematically identifying, grouping, and ranking (in order of frequency) the appearance of similar terms and applications in order to observe tendencies and themes for each type of resilience. Results of this analysis allowed for the identification of basic structure, most frequent terms, and general tendencies observed across resilience conceptualizations. A critical analysis of these results supported the construction of a (proposed) definition for resilience (see Section 3.2).

2.2.2. PART II: Conceptual basis of resilience theory

For a more complete understanding of resilience conceptualizations, it was necessary to identify the theoretical assumptions that constitute the conceptual basis for resilience as applied to the field of climate change. As in similar investigations (Downes et al., 2013a), a pilot study was performed for a sample of papers to identify recurring concepts (themes) representing the foundations or assumptions of resilience theory. Next, a quantitative analysis (text search and manual review) was conducted for all documents to calculate the (relative) recurrence of these concepts. Finally, a qualitative thematic analysis was conducted to examine, in detail, the meaning of each of these categories (see Section 3.3).

2.2.3. PART III: Determinants (characteristics) of resilience building

To allow for a more comprehensive consideration of the proposed definition of resilience within the context of relevant conceptual bases and to support guidance for resilience assessment, key social and ecological 'determinants' (Adger et al., 2011; Ebi, 2011; Keim, 2008) of resilience, the 'attributes' necessary for the construction of each determinant, and existing and potential 'indicators' for these attributes were identified (see Section 3.4).

3. Results

3.1. Reporting on climate change resilience is increasing, predominantly of social and social-ecological resilience

The overwhelming majority of papers were published in the most recent years included in this review. Figure 2 presents a summary of search results and document selection. The literature search returned a total of 1805 documents, 701 documents were included after conducting Revision 1, and 151 documents were included after Revision 2 (a complete list of the 151 papers selected for analysis is included in Annex 1).

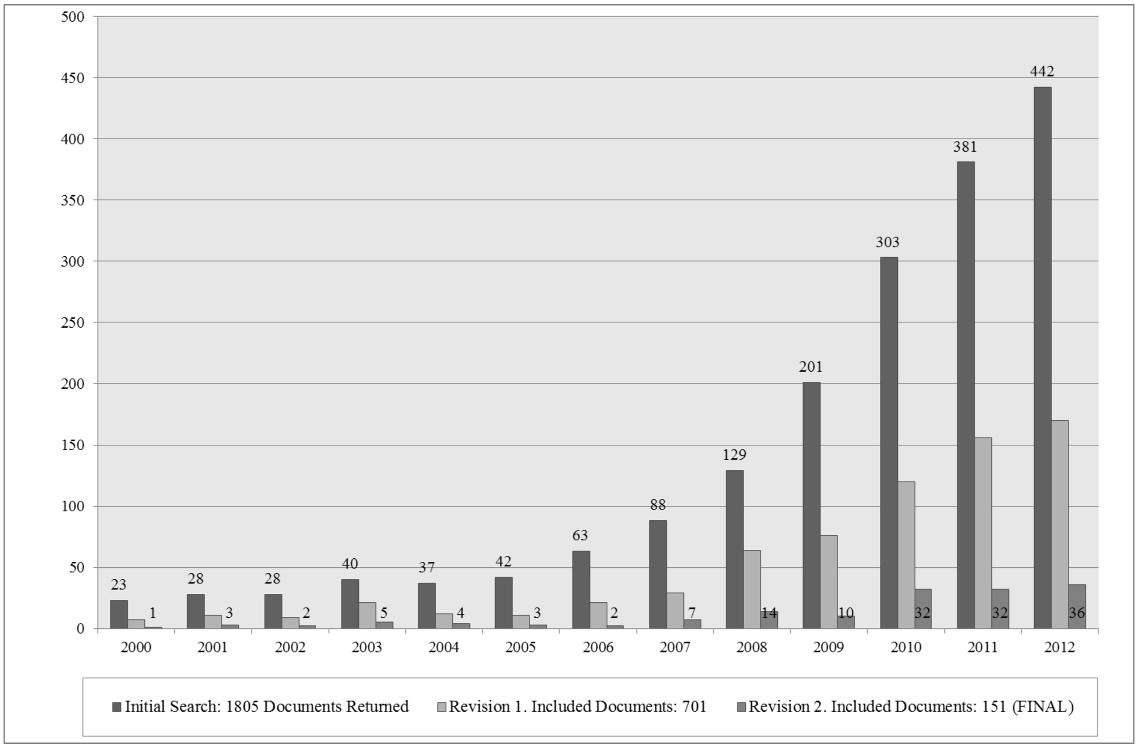

Figure 2. Summary of search results, document selection, and final inclusion

3.2. Proposal of resilience conceptualization

In this section, results of the review and analysis of resilience conceptualizations are provided. Specific references to the sources associated with results are not included here in an attempt to save space and improve readability. Annex 1 provides a complete list of reviewed papers.

3.2.1. Resilience defined as capacity

Results presented in this section emerge from Part I of analysis. Figure 3 displays the distribution and overlap of explicit definitions of social, ecological and social-ecological resilience identified within reviewed literature; Annex 2 details the relationship between results of the definition deconstruction and specific source papers. As resilience types are not mutually exclusive, one paper may provide a definition for more than one type of resilience. Structural/physical resilience definitions are not represented because only three were observed.

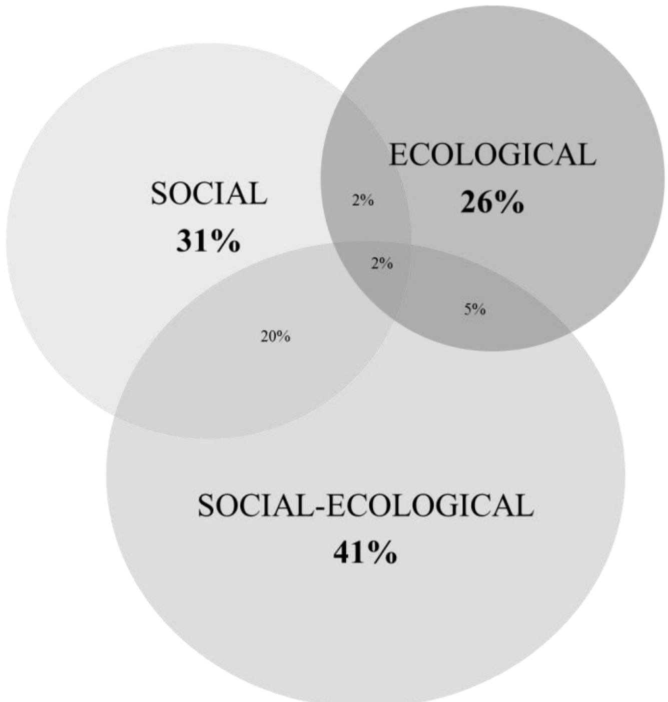

Figure 3. Distribution of reviewed literature by resilience type

Note: Not every reviewed document provided an explicit resilience definition, and some papers provided more than one definition. Percent values are calculated based on the total number of definitions; definitions of structural/physical resilience correspond to 2% of total definitions.

Reviewed papers presenting explicit resilience definitions most frequently (41%) define social-ecological resilience; 31% describe social resilience, and 26% define ecological resilience. The greatest overlap of various resilience types within papers describing more than one type of resilience is observed between social-ecological resilience and social resilience. Ecological resilience presents lower overlap.

Resilience conceptualizations within climate change literature demonstrate a strong tendency (observed in 94% of resilience definitions) to describe resilience as an ability or capacity, represented in Figure 4 as “A”. Definitions frequently describe these abilities or capacities (which are often represented by verbs in their infinitive form) as linked to two factors: resilience in the face of external forces or events, as represented in Figure 4 as “resilience to what” (“B”); and resilience “in order to” (“C”).

Few sources waver from the structure of definitions presented above. These sources define resilience as the degree, amount, or magnitude of disturbance or alteration that a system or social entity can absorb, without losing structure, processes, and function, as the amount of change that can be tolerated before a critical threshold is reached and passed, or as the speed or rate of recovery. As mentioned in the previous paragraph, the majority of papers define resilience following the structure illustrated by Figure 4.

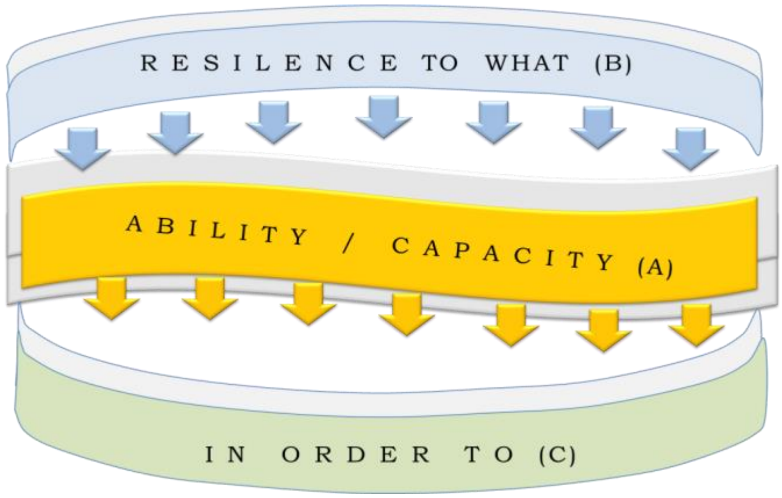

Figure 4. Deconstructing resilience definitions
Resilience is frequently defined as an ability or capacity for "A", to "B", in order to "C".

Abilities and capacities described by resilience definitions were grouped by meaning in order to consolidate similar definitions of resilience and make possible the observation of overall tendencies. Table 2 indicates those terms considered to be similar, grouped by column heading. "Others" refer to less frequently occurring yet nevertheless notable concepts observed within definitions of resilience.

Table 2. Resilience as ability or capacity

to absorb	to adapt	to maintain	to recover	to respond	to resist	to anticipate	others
to withstand	to (be) changed/ accept change	to retain	to return	to react	to reflect	to prepare	to (self) (re) organize
to tolerate	to accommodate/ adjust to	to sustain	to 'get back'	to engage		to plan	to learn
to deal	to move	to continue	to rebound	to address			to innovate
to cope			to re-establish				to seek/to find
to face							

Note: Synonymous or similar verbs are grouped by column; "others" refers to less frequently appearing concepts

Using Figure 4 as a template, we diagrammatically present tendencies and the components "A", "B", and "C" observed in reviewed resilience definitions (Figure 5). Analyzing resilience definitions by resilience type allowed for the observation of differences in the emphasis, interpretation and connotation given to key elements by each of these types.

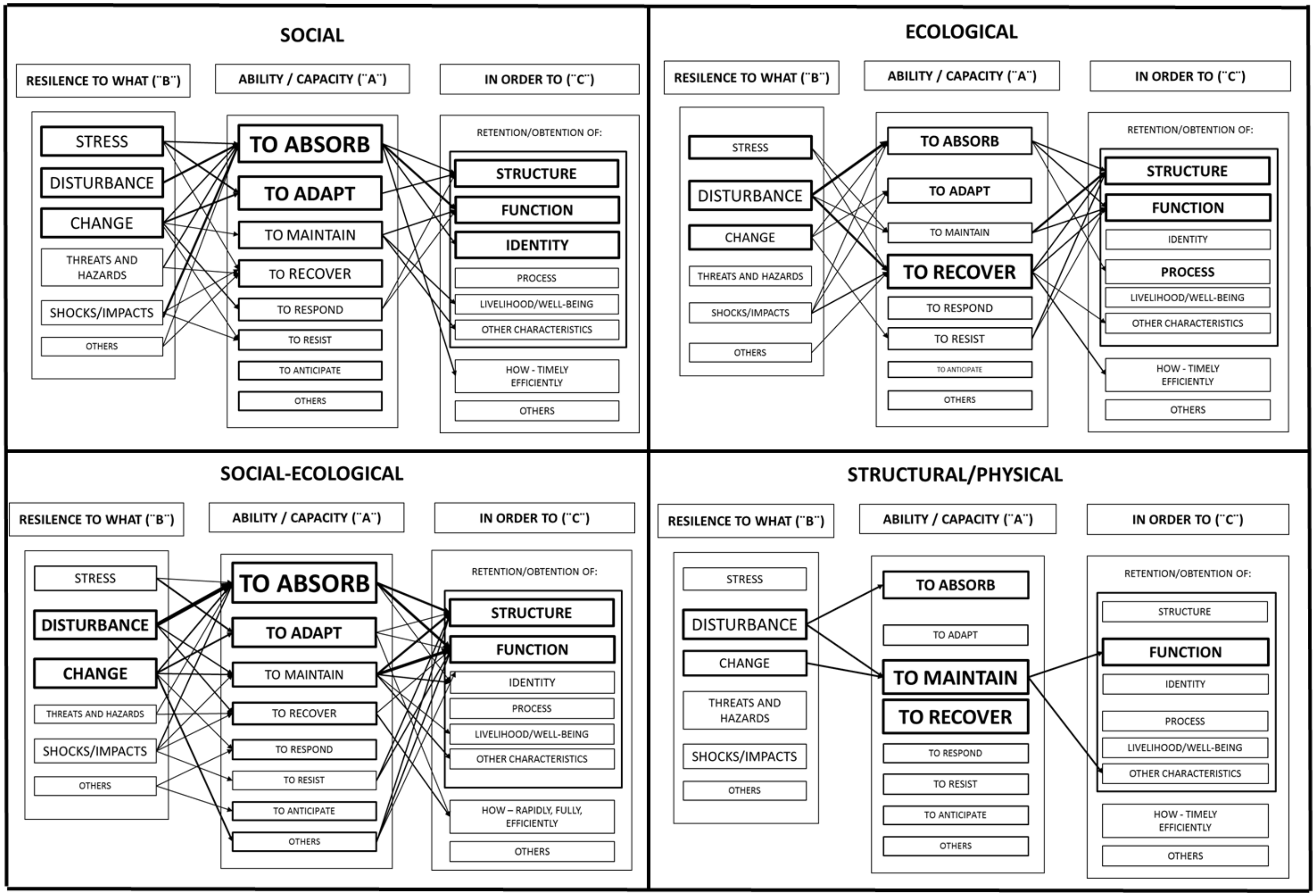

Figure 5. A roadmap of resilience definitions by resilience type

N total = 103. Sub-division (not mutually exclusive): Social 42, Ecological 35, Social-Ecological 56, Structural/Physical 3.

Note: Main elements of observed definitions of resilience types and their interconnections are represented.

Font size and arrow thickness indicate relative importance.

Most notably, definitions of social and social-ecological resilience emphasize absorbing and adapting, while those of ecological resilience focus on a capacity for recovery. Definitions of structural/physical resilience are few and it is therefore difficult to observe their tendencies with much certainty; nevertheless, it is in these definitions that (not surprisingly) the idea of maintaining or returning to a previous state remains dominant. These results demonstrate the diversity and variation of resilience definitions; even if certain terms are used to convey similar meanings, subtle differences between terms and the favoring of one term over another is worth noting as these differences might have impacts when applying resilience ideas to practice.

3.2.1.1. Social resilience

Ability or capacity "A"

Social resilience is most frequently described as an ability to absorb, to adapt, to maintain and to recover. Social resilience is less frequently described as a capacity to respond and to resist. Definitions occasionally refer to a capacity to anticipate and to self- or re-organize. Resilience was also occasionally described not as an ability but rather as a process, for example, as a process leading to a desired outcome, related to adaptive capacity and function in the face of (and post-) disturbance, and to dealing with unexpected situations. Additional definitions refer to resilience as change at the margins; as openness and adaptability; as an ability to seek out or find, to improvise, to develop and as 'bouncing forward'; as a function of awareness and management of vulnerability; and as an ability or willingness to learn and an interest in changing behavior.

Resilience to what "B"

Observed capacities and abilities are discussed in relation to external forces or events. Most often, social resilience is defined as capacity in the face of stress, stress from change, or stressors, and of disturbance, climate disturbance, or perturbation. Also common are definitions of social resilience in the face of change or changing conditions; of climate variability or shifting climate circumstances; of threats, hazards, or the effects of a hazard, and of emergency risks.

Several papers also refer to social resilience in the face of shocks to infrastructure or to social infrastructure, or the impacts of these shocks. Sources also describe social resilience in the face of internal (not only external) crises and of adversity.

In order to "C"

Frequently, social resilience in the face of external forces is described as having the ultimate goal of preserving, reaching, or returning to basic structure, function, process, and identity, to healthy functioning, or of continuing as expected. Similar objectives include the maintenance of social coherence, of livelihood and well-being, of functions supporting this well-being, or of functions of 'creation' and 're-creation'. It is argued that resilience as recovery should be timely and efficient and should minimize damages, and that resilience promotes finding opportunities and 'the silver lining' of challenging situations.

3.2.1.2. Social-ecological resilience

Ability or capacity "A"

Definitions of social-ecological resilience most commonly describe ability (or related capacities) to absorb, to adapt, to maintain and to recover; an ability to respond is mentioned less frequently. Within this type of resilience, abilities to self- and/or re-organize and to learn are often described, with a focus on a continuous and incremental building of learning capacity. Some papers extend resilience conceptualization to an ability to innovate and create and as a capacity to anticipate or to reduce vulnerability.

Resilience to what "B"

Most often (as for social resilience), social-ecological resilience is described in the face of disturbance or perturbation; of change and specifically to external changes; or of stress or shocks. Social-ecological resilience less frequently confronts impacts, hazards, threats, or their effects, shifting conditions or circumstances, disasters or events, unexpected crises, and adversity.

In order to "C"

Social-ecological resilience aims to preserve or restore (actual or potential) function, and to safeguard structure or form. Emphasis is given to the idea of stability or acceptable levels of function, of returning to a previous and/or stable state and the avoidance of a shift to an undesirable one or the loss of key system properties. More specifically, social-ecological resilience aims to preserve patterns of behavior, feedbacks, identity and integrity. The idea of alternative states and a shift toward an improved state is mentioned.

Social-ecological resilience not surprisingly considers the importance of ecological services, and therefore aims to preserve an adequate supply of goods and services and provide for well-being, allowing a system to remain productive and profitable within the means of available resources.

3.2.1.3. Ecological resilience

Ability or capacity "A"

Diverging slightly from the tendencies observed for social and social-ecological resilience, ecological resilience is primarily defined as an ability (or related capacities) to recover, to absorb, and to adapt. Abilities to maintain, to resist, to survive and to re-organize are mentioned less frequently. One source describes evolutionary resilience as an ability to persist or undergo adaptation, and approximates resilience to response, resistance and transition.

Resilience to what "B"

Ecological resilience is described (as are social and social-ecological resilience) in the face of disturbance or perturbation; of change, change in variables and parameters, lasting change caused by disturbance, or changing environmental conditions; or in the face of impacts, shocks, stresses, stressful events, or pressures.

In order to “C”

Ecological resilience aims to preserve previous state, structure, functions or processes, feedbacks, or desired conditions or characteristics; in order to persist and to return to normal growth rates. In the case of marine systems, resilience pursues the preservation of diversity.

3.2.1.4. Physical/structural resilience

Ability or capacity “A”

Mentions of physical or structural resilience were few and differ from the other three types of resilience analyzed; resilience is described primarily as an ability to maintain, as a capacity to recover, and as an ability to absorb or return.

Resilience to what “B” and in order to “C”

Abilities related to structural or physical resilience are described in the face of disturbance, disruption, and change, with the purpose of preserving function as expected, previous, stable state, and an acceptable level of service availability.

3.3. Conceptual bases of resilience theory when applied to climate change (primary supporting theoretical assumptions)

Section 3.2 presented an analysis exploring the core elements within resilience definitions in climate change literature. In order to support the ‘reconstruction’ of our resilience definition and provide guidance for its operationalization in practice (attempted in Section 4), further clarification of the key supporting theoretical assumptions of resilience theory when applied to climate change literature was required (Part II). Table 3 presents the results of Part II to identify the conceptual bases of resilience theory.

Table 3. Conceptual bases of resilience theory: Theoretical assumptions

Theoretical assumption	Frequency of appearance (%)	Detail[+]	Description
Change	100%	External (100%)	Refers to an alteration of external conditions or circumstances (often, climate change)
Systems	83%	Social* (49%), ecological* (56%), and/or social-ecological* (36%) - at least one of these: 100%	Social systems (e.g. communities), ecological systems (ecosystems), or systems comprising social and ecological components and their interactions (social-ecological)
		Dynamic (43%), complex (65%), complex adaptive systems (12%) - at least one of these: 76%	Describes system characteristics and capabilities
		Integrated (10%), coupled (13%), connected* (36%), linked (16%) - at least one of these: 57%	Refers to a consideration of the connections and interactions within and between systems
Scale	74%	Spatial* (61%)	Involves a recognition and consideration of varying spatial scales
		Temporal* (47%)	Refers to a recognition and consideration of varying temporal scales
		Multi*- (49%)	Implies a recognition and consideration of numerous scales
		Cross*- (21%)	Denotes inter-scale interactions, between and across varying scales
Uncertainty	62%	External (100%)	Refers to a lack of awareness of exact impacts and/or outcomes, or of future conditions; external refers to context or setting
System elements or components	A clear majority of papers refer to the multiple elements or components relevant to resilience and/or resilient systems		

Note: All searches were guided using the text search option within NVivo 10.

[+] Documents may be classified within more than one sub-concept; these groupings are not mutually exclusive.

* Indicates that alternative phrasing was included within count.

Not surprisingly, all reviewed documents discuss resilience in the face of external change (climate or otherwise). A majority of papers (over 80%) explicitly describe social, ecological, and/or social-ecological systems. Over three quarters of these systems are described as dynamic, complex, and/or complex adaptive, and over half as integrated, coupled, connected and/or linked. A consideration of scale is also fundamental to resilience theory; almost three quarters of reviewed papers refer explicitly to the importance of scales and their consideration within resilience evaluation and application; about half of the time these scales are described as spatial and/or temporal. Approximately 60% of papers refer to an intrinsic uncertainty of (future) context or setting and the relevance of an awareness and consideration of this uncertainty to resilience building. A clear majority of papers describe systems as composed of distinct elements or components. However, owing to the wide variety of terms and divisions used to describe this concept (e.g., systems are composed of multiple elements), it was not possible to calculate a comparable frequency of occurrence within sampled literature.

An understanding of these conceptual bases and their prevalence within reviewed literature is critical for effective resilience assessment and building.

3.4. Key determinants (characteristics) of resilience building

Part III of analysis, a review of multi- and cross-disciplinary conceptualizations of resilience, leads to a logical division of the various determinants (components) of resilience into social and ecological subsystems. This division is neither clean nor perfect, but is necessary to methodological considerations for the analysis of these components, their characteristics and their complex interactions.

As argued by Walker et al. (2006), although it is possible to identify social and ecological components, the process of breaking down a system into parts for the purpose of analysis is not simple or easy. This is owed in part to the fact that, as described by Berkes and Folke (2000), the social and ecological components of a given system should not be considered as ´given´ or static; rather, these components are dynamic as well as deeply and complexly interconnected. Walker et al. (Walker et al., 2006) propose that these “ecological and social domains of social-ecological systems can be addressed in a common conceptual, theoretical, and modelling framework”.

To most effectively present and analyze the results of this review while responding to the need for a more comprehensive integration of the social and ecological components than that observed in most of the literature reviewed by this study, which continues to divide these components, we propose an understanding of resilience within social ecological systems and their components as presented by Figure 6.

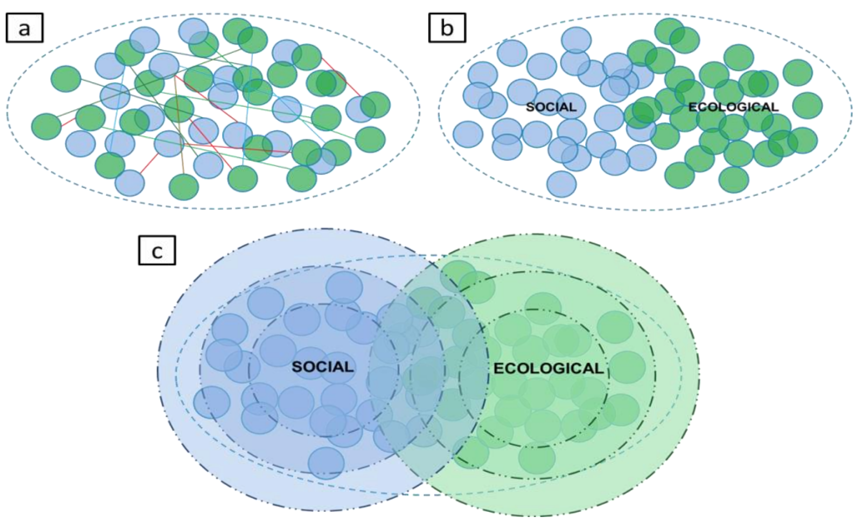

Figure 6: Methodological approximation of social and ecological component division (a: Interconnected, overlapping components of a social-ecological system; b: approximate, imperfect identification of these components as social or ecological for the purpose of analysis; c: understanding resilience of systems with overlapping and intrinsically connected social and ecological components.)

Literature was reviewed for those characteristics repeatedly described as essential to resilience building, or determinants of resilience (Adger et al., 2011; Ebi, 2011; Keim, 2008). Various attributes for each resilience determinant as well as existing and potential indicators were also identified. A detail of observed determinants, attributes, and attribute definitions is provided in Table 4.

Table 4. Key determinants for resilience building

DETERMINANTS OF SOCIAL RESILIENCE			
DETERMINANT	**ATTRIBUTE**	**DEFINITION**	**RELATION TO LITERATURE***
Self-organization	Potential for self- and/or re-organization	Ability of local actors, communities or social systems to proactively, dynamically and flexibly organize (re-configure) themselves and modify actions following a disturbance.	P7/P100/P101/ P126/P133
	Space for improvisation and innovation	Individual or collective ability to improvise and modify current and/or to implement new ideas, approaches or programs; this requires flexibility and local creativity, the discussion of alternative values and methods, and/or reframing for problem solving.	P44/P98/P117/ P126/P130/ P153
	Resourcefulness	Ability to involve community and mobilize available internal resources to achieve goals (to repair, reorganize, or respond to challenges).	P81/P131
Social capital	Leadership	The presence of community leaders and collective leadership; this requires the support of local authorities and permits an increase of accountability and the potential to influence decisions being made at the local scale.	P16/P19/P102/ P126
	Social networks	Presence, expansion and diversity of individuals and groups and their networks and connectivity by promoting collaboration in order to achieve, for example, social support, relationships, knowledge and information sharing, co-learning, and the exchange of good practice.	P16/P85/P116/ P121/P131
	Citizen participation	The level of involvement in activities and participation in collective action by community members; reflects a need for community action, to improve and broaden citizen engagement, and for increased involvement and public awareness.	P85/P102/P12 1/P126/P133
	Education/information	Opportune, equitable and universal access to information and education about, for example, awareness programs and warning systems related to risks, threats, and opportunities; broadly educated societies appear to be more resilient.	P2/P126/P139/ P161
	Place attachment/Sense of community	Place attachment, residents who remain in an area for a length of time and territorial identity are enhanced by and support a sense of community, trust, interaction, cohesion, and community members who work together for common goals.	P34/P44/P131
Learning	Experiential learning	The ability to learn from and internalize past experiences and failures as primary sources (e.g., disasters) and to modify oneself in the face of changes in order to avoid the repetition of past mistakes and exercise caution in future decisions; ‘‘learning-by-doing’’. Experiential learning is often used to describe individual leaning.	P2/P81/P95/ P108/P136
	Social-collective memory/social learning	Social memory represents accumulated knowledge within a social group, stored or latent potentials for renewal and reorganization, and/or “experiential grounding”. Social learning is the collective action and reflection that occurs among individuals and groups as they work to improve a situation, and the ability to learn collaboratively by sharing knowledge, practices and past experiences.	P79/P85/P86/ P95/P45/P90
Information	Information and technology	Access to and coherence, clarity and symmetry of information. Availability and flexibility of technology required to translate desirable interventions into practical applications and manage for the future.	P26/P85/P101/ P102/P129/ P162
Planning and response	Preparedness	Ability to anticipate and prepare and plan for change and uncertainty by shaping responses, strategic planning initiatives and warning systems, and mitigation and prevention actions.	P25/P44/P53/P 79/P81/P90/ P94/P131
Governance and co-management	Diversity	Variety and extension of actors available (multi-actor, multi-sector, multi-level) to accommodate complexities and uncertainties; multiplicity of available options, capabilities, and response approaches; potential for livelihood diversification.	P21/P50/P62/P 74/P77/P84/P9 5/P105/P135/ P163
	Organizational linkages, collaboration and cooperation	Partnership initiatives and collaborative approaches ensuring multi-level, multi-sector and cross-scale networks between actors and agencies that bring these together in a mutually beneficial relationship.	P33/P44/P50/P 53/P95/P105/P 116/P126

	Availability of institutions and mandates	Development and availability of a range of national and local institutions (e.g., research, policy, technical) allowing for the development of responsive and flexible adaptation practices for a specific context.	P95/P133
	Decentralization	Distribution of governance to facilitate an exchange of knowledge and sharing of resources and promote local responsibility for self-management and more balanced decision-making amongst actors and across scales.	P101/P102
	Redundancy	A degree of overlapping function and alternative strategies or means of providing warning, coordinating, or achieving a goal; insurance to cope with sudden and uncertain change, disruption or degradation.	P2/P74/P81/ P95/P130/ P136
	Adaptive management	Flexibility to modify management structure and strategy on the basis of new information and ongoing evaluation; managing for change, pressures, and shifting interactions between society and ecosystems by supporting an ability to change and adopt alternative strategies (short- or long- term).	P16/P45/P57/ P99/P136
	Accountability	Actors who assume responsibility for their public pledges and actions; this requires consciousness and transparency to make the most of existing powers and responsibilities.	P19/P41/P111/ P126
Resources	Availability	Accessibility of and ability to mobilize economic and human resources, and the distribution of these resources.	P71/P95
	Diversification	Diversity of resources and of the means of their delivery to safeguard against a failure in their supply; economic and income diversification to reduce vulnerability.	P2/P71
Adaptability	Adaptive capacity	The ability to shape change in response to disturbance; necessary, networked pre-conditions for adapting to change and new conditions in a timely manner in order to implement effective adaptive measures.	P16/P33/P41/ P62/P77/P95/ P104/P100/ P130
	Adaptation	Implementation of actions, strategies and planning to accommodate the positive and reduce the negative effects of change.	P2/P86/P95/ P118
DETERMINANTS OF ECOLOGICAL RESILIENCE			
DETERMINANT	**ATTRIBUTE**	**DEFINITION**	**RELATION TO LITERATURE***
Variety	Diversity	Genetic diversity and diversity of species and functions to safeguard ecosystem processes, fortify response capacity, and support the potential for reorganization and renewal.	P4/P6/P9/P10/ P49/P53/P65/ P112/P124/P157
	Redundancy	Species redundancy and degree of overlapping function or alternative means of achieving a goal; redundancy to provide insurance to cope with sudden change, disruption or degradation and maintain ecological processes.	P2/P6/P29/P49/ P74/P80/P156/ P157
Feedback	Feedback/ connectivity/ interactions	Effective multi-directional interactions, flow, connectivity, and feedbacks between system components to maintain system function and structure and enable adaptation.	P2/P4/P9/P43/ P49/P65/P72/ P74/P80
Self-organization	Self- and/or re-organization	Flexibility for self- and/or re-organization or renewal under changing conditions to preserve actual and potential functions.	P2/P10/P33/ P111
Adaptive capacity	Adaptation (action)	Ongoing modification of ecological systems and their processes and patterns in response to change in order to maintain function and persist.	P2/P43/P103
	Evolutionary potential	Potential of populations to evolve in response to stressors and change expressed as a dynamic process involving population dynamics and evolutionary forces such as genetic drift, mutation and migration.	P124
Resources	Diversification	A diversity of resources and the means of their delivery; these can help mitigate external shocks and stress.	P2
	Abundance	Resource availability (reservoirs) and rate of resource movement and replacement in order to maintain ecosystem functions and components.	P2/P29
Robustness	Robustness	Resistance to and potential for restoration following impacts and stress.	P80/P130/P146
Buffering	Buffering capacity	Capacity and flexibility (malleability) to absorb disruption and buffer ecosystem processes, function and structure in the face of changing conditions.	P6/P27/P29/P31/ P104

*Relationship to the literature: numbers correspond to the source(s) of the material included in the table. Annex 1 presents a list of all reviewed documents and their corresponding numbers.

4. Discussion - Guidance for resilience building and assessment

The theoretical evolution of resilience is well understood. On the one hand, the proliferation of the application of resilience within multiple disciplines has lent richness and diversity to the understanding of its conceptualization. On the other hand, ambiguity in the definitions, conceptualizations, building and assessment of resilience emerges and has the potential to confuse researchers and practitioners. In doing so, this ambiguity distracts from effectively dealing with this diversity, and therefore has the potential to compromise the effectiveness of political and institutional initiatives responding to a changing climate (Djalante and Thomalla, 2011; Downes et al., 2013b; Manyena, 2006).

The relevance of our systematic review and critical analysis of existing knowledge is exemplified in its attempt to deal with diversity and complexity, not by reducing but rather by structuring and cataloging diverse understandings of resilience, and exploring how these understandings may be operationalized within real world applications. Firstly, we structure and present the theoretical assumptions that must be considered for resilience building and assessment. Secondly, we propose a definition of resilience as a guide for application specifically within the climate change field. Thirdly, we identify key determinants of resilience and their attributes and potential indicators for resilience building and assessment. Finally, we critically analyze resilience as a concept and its relationship to other concepts.

This investigation aims to support the work of investigators, practitioners and policy makers, with the hopes of directing future research and advancing the incorporation of resilience as a theory within practical applications.

4.1. Key theoretical assumptions to be considered for building resilience to climate change

Our conceptual framework of resilience rests upon a base of theoretical assumptions, a consideration of which is imperative to the effective observation, evaluation and construction of resilience within social-ecological systems and applied to climate change.

A resilience framework must consider that systems are constituted by social and ecological components, and that these components are deeply and complexly connected to one another. In addition, a resilience framework should be applied within a necessarily delimited system, one which is arbitrarily defined by the investigator or practitioner for methodological or practical purposes. Nevertheless, it is important to bear in mind that an absolute delimitation for a given social-ecological system does not exist in the real world; systems are not isolated but rather embedded within a network of other, interconnected and related systems (Adger et al., 2005; Berkes, 2007). Any proposed delimitation for investigation, the implementation of public policy, or for other purposes, necessarily possesses a level of subjectivity, and these limitations should be considered, especially as they relate to results and their analysis. In the same way, any investigation or implementation of a resilience framework should also incorporate multi- and cross- (spatial as well as temporal) scale analysis (Alliance, 2010). Spatial scale is important because actions are dependent upon and influence other actions on different spatial levels; for example, legislation generated on a national level has impacts on a local level. Temporal scale must also be considered; a given system is the result of past actions (for example, natural disaster planning) and of future actions (for example, climate change modeling and projections of the magnitude and frequency of threats) (Aldunce et al., 2015; Downes et al., 2013a).

It is clear that the resilience of social-ecological systems faced with external disturbance (in this case resulting from climate change) exists within an intrinsic uncertainty of (future) context or setting. Despite a multitude of existing studies conducted in the climate change field, there exists no absolute certainty regarding the magnitude or intensity of future changes, only a certainty that they will exist (O'Brien et al., 2010). The recognition and consideration of climate change uncertainty is fundamental to resilience building. For this reason, we dedicate several paragraphs to addressing this uncertainty.

It is important to prepare for an uncertain context, considering not only the range of potential change and its impacts, but recognizing that uncertainty exists *within* social-ecological systems; for example, the very goals and values of a given society or context may vary (Roman et al., 2010). Systems are complex and display potentially unknown and emerging interactions and properties (i.e., complex adaptive systems) and as a result present responses with a degree of uncertainty; projected changes may or may not occur, and other, unexpected changes may present themselves (Berkes, 2007).

Uncertainty is therefore an inherent characteristic of systems within the context of climate change, and systems must learn and develop capacities in order to live with this change (Folke, 2006; Miller et al., 2010). As a result, this uncertainty represents an essential consideration within the public sector; national adaptation policies must base their actions on possible climate scenarios. Resilience supports the exploration of policy options within this uncertain context (Tompkins and Adger, 2004); there is a need to work towards both a decrease of uncertainty through improved predictions and to promote preparation for those changes that cannot be predicted (Berkes, 2007). This uncertain context can also result in a paradigm shift, towards an emphasis on (adaptive) capacity building within changing circumstances.

The principal challenges presented by the resilience perspective, both for decision makers and practitioners applying resilience to research or policy making, include a need to deal with uncertainty, defining the system under study, and working on and between different scales and with diverse actors. A diversity of ideas and perspectives can be useful for overcoming these challenges (Aldunce et al., 2015; Barnett, 2001).

4.2. Proposed definition of resilience

Recognizing the diversity of existing resilience definitions resulting from multiple epistemological roots and the diversity of contexts giving origin to these definitions, we performed a critical analysis of observed tendencies in order to propose a definition of resilience.

We acknowledge the limitations of the proposal of any one definition of resilience, and our proposed definition of resilience by no means represents the only possible definition for the term, nor do we believe that an extreme simplification of the concept is possible. Nevertheless, we believe that a base definition of resilience is useful for the potential application (or operationalization) of resilience theory in practice.

Based on our review of the structure and content of existing resilience definitions (Part I) and theoretical assumptions (Part II), and a critical analysis of observed overall tendencies, especially within literature from most recent years, we propose the following definition of resilience in the context of climate change:

Resilience is the ability of a social-ecological system to plan (anticipate), to respond (absorb) and to adapt to climate variability, change, and hazards, and to explore opportunities in order to continue functioning as a system.

Each part of this definition emerged from a critical analysis of the results of Part I.

Resilience is the ability of …

A majority of definitions describe ability or capacity. Here we have selected ability and understand it as the possession of means, skills, or capacity to do something; this implies potential as well as actual capacity.

… a social-ecological system …

The presentation of these systems as coupled ("-f") recognizes their nature as intimately and intrinsically linked. A separation of social and ecological systems and their components may be necessary for analysis and methodological purposes; nevertheless, they must always be understood as interconnected. The focus of a given analysis will determine the relative importance of each (social or ecological) element and their interconnections.

… to plan (anticipate), to respond (absorb) and to adapt to …

An ability to plan is especially relevant within the context of climate change and must address both short-term impacts (such as extreme events) and longer-term effects (such as climate variability). A tendency to include this ability was observed in the most recent resilience conceptualizations.

An ability to respond corresponds to the category 2 (see Table 2) "to absorb", and represents the most frequently occurring capacity described by resilience definitions. "Responding" implies absorption while suggesting an additional capacity for reaction and recovery.

An ability to adapt reappeared frequently within resilience definitions. Adapting implies action beyond a simple or automatic response; it involves a search for opportunities for system improvement.

… climate variability, change, and hazards, and to explore opportunities…

Climate change implies a combination and interaction of natural and anthropogenic factors. Change and hazards were described relatively frequently within observed definitions of resilience.

With the terms "climate variability, change and hazards" we respond to the need for a definition of resilience explicitly within the context of climate change. Although variability appeared relatively infrequently within observed definitions, we believe it is important to a comprehensive inclusion of the potential impacts of climate change, which not only derive from long-term change but also from the effects of climate variability. In addition, referring to change and variability, and not solely to climate stressors, serves to maintain the possibility of a positive interpretation of these factors, and the potential to explore and take advantage of positive opportunities that may be generated by this change.

… in order to continue functioning as a system.

With this part of the definition, we maintain the possibility of system change and improvement, not necessarily requiring a return to previous conditions but rather focusing on the preservation of the most fundamental properties (Aldunce et al., 2014).

Table 5 presents definitions of various international and research bodies (IPCC, Stockholm Resilience Centre, Resilience Alliance).

Table 5. Existing resilience definitions

Source	Definition
IPCC 2007	*The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (IPCC, 2007).*
Stockholm Resilience Centre 2007	*Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds.*
Resilience Alliance, 2002	*Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems (SES). "Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:* • *The amount of change the system can undergo and still retain the same controls on function and structure* • *The degree to which the system is capable of self-organization* *The ability to build and increase the capacity for learning and adaptation.*

In order to assist the operationalization of resilience, our definition attempts to include those components essential to resilience within a specifically climate change context, and to present these components within a straight-forward and logical structure, in order to obtain maximum clarity of interpretation and facilitate application.

4.3. The Resilience Wheel: A guide for resilience assessment and practical application

The "Resilience Wheel" is a diagrammatical representation that facilitates the visualization of the determinants and attributes necessary to resilience building identified in Section 3.4, and serves as a guide for policy makers and investigators, supporting the evaluation of distinct social and/or ecological contexts and scales. We developed this representation based on the "Adaptive Capacity Wheel" presented by Gupta et al. (2010). When applying the Resilience Wheel, it is important to consider that an incorporation of every attribute may not always be necessary; each application of the Wheel will require its accommodation and a prioritization of those attributes most relevant to a given context, and the selection of determinants will depend upon the discipline and focus of a study. Figures 7a and 7b present the resilience determinants (inner ring), attributes (outer ring), and some examples of indicators in the form of Social and Ecological Resilience Wheels (all based on Section 3.4).

Given that resilience is context-dependent and is subject to influence by the territory and scale of analysis (Aldunce et al., 2014), we developed a simple and generalized definition of the concept, understanding that the determinants and attributes of resilience represent the real richness, content, and characterization of resilience within each context of analysis, and the key to applying our proposed conceptualization within distinct realities.

The selection of determinants for any given context will depend upon the focus of investigation or application and on the scale of analysis. Despite the fact that the inclusion of numerous determinants better reflects the various characteristics of a system, as McClanahan et al. (2012) indicate, "while intuitively appealing, including large numbers of factors in a resilience assessment may be both impractical and ineffective". Nevertheless, the selection of resilience determinants should be well supported and justified, as the over-simplification of inherently complex systems may lead to erroneous conclusions.

As described in Section 3.4, a review of multi- and cross-disciplinary conceptualizations of resilience leads to the logical division of the various determinants of resilience grouped primarily into social and ecological subsystems. We recognize, however, that this division does not reflect reality, and that therefore, the effective application of the Resilience Wheel will require a consideration, inclusion, and integration of determinants from both the Social and Ecological Wheels.

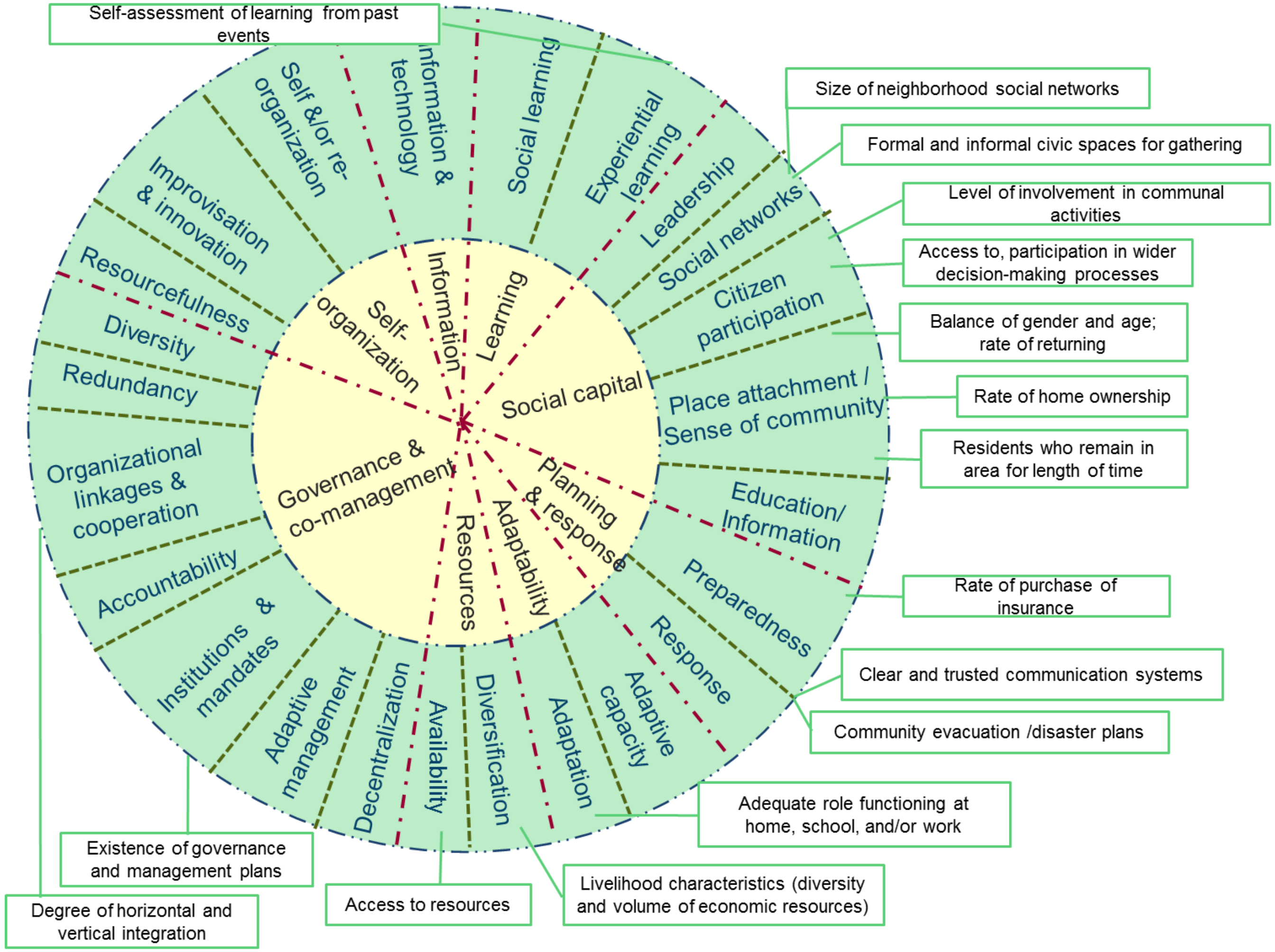

Figure 6(a). Social Resilience Wheel

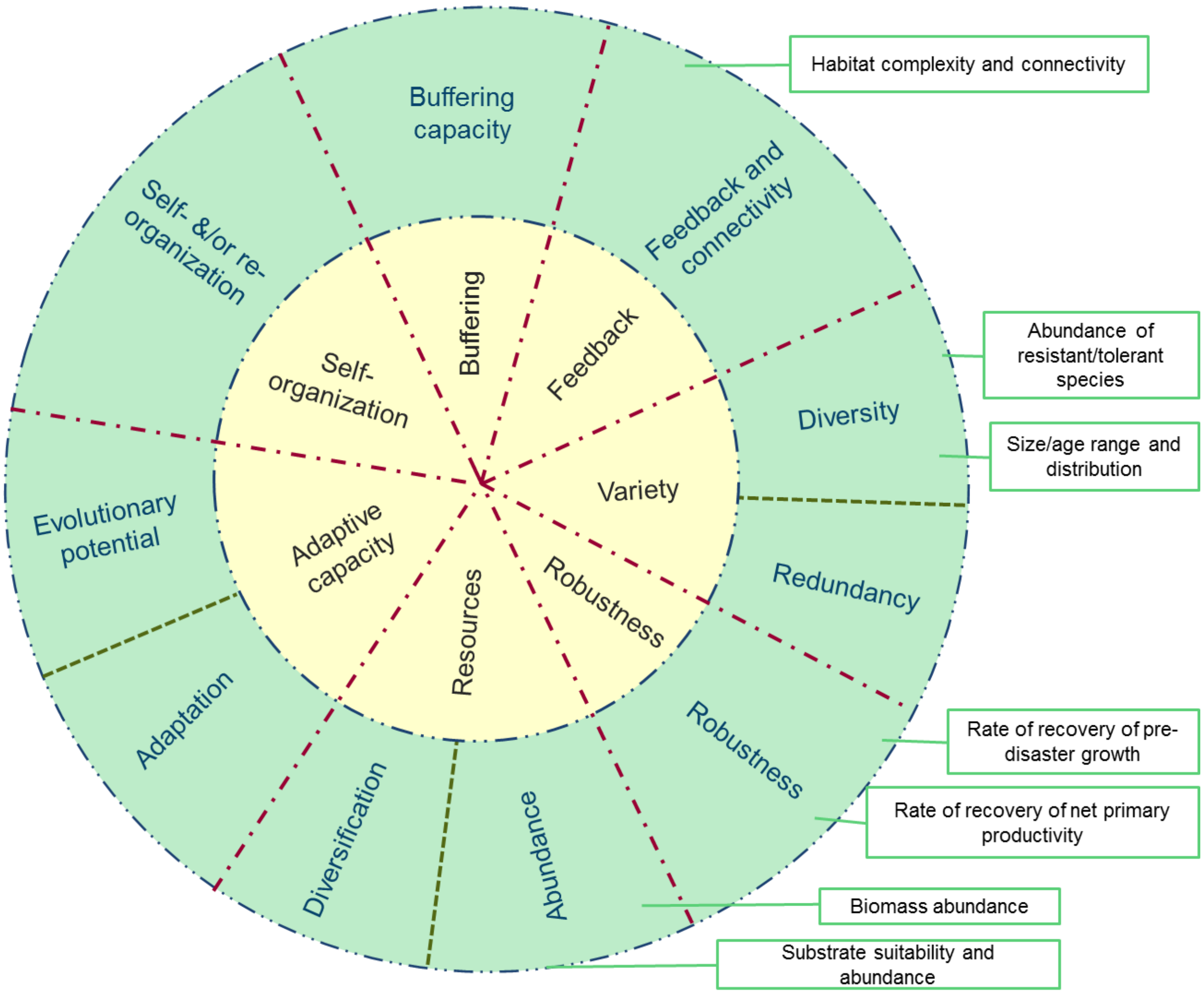

Figure 6(b). Ecological Resilience Wheel

4.4. Resilience as related to other central climate change concepts

Resilience theory as a perspective represents a holistic and integral interpretation of social-ecological systems, allows for a consideration of potentially positive impacts and opportunities derived from external climate factors, and recognizes the importance of not only adaptation but additionally flexibility as a central system characteristic - i.e., the ability to change, evolve and adopt alternative strategies (either in the short or long term) in response to changing conditions (da Silva et al., 2012). Resilience also notably assigns explicit relevance to several key system characteristics: self-organization, learning, and uncertainty. Resilience represents a valuable complement to related climate change concepts, and even presents some advantages over these concepts. Resilience additionally encompasses related concepts such as adaptation, adaptive capacity, transformation, and vulnerability, and presents both a valuable complement to as well as some comparative advantages over these existing concepts within the climate change context. Therefore, advancing the practical utility of resilience within the current context of change and uncertainty is both desirable and necessary.

In this section we relate and contrast resilience with other important concepts in the climate change context: vulnerability, adaptation and adaptive capacity, and transformation.

Vulnerability

Although vulnerability is sometimes considered the 'flip side' or opposite of resilience (many sources indicate that a reduction of vulnerability implies an increase of resilience (Bravo, 2009; Olwig, 2012; Walker et al., 2011)), the relationship between vulnerability and resilience is not necessarily one of a simple inverse nature (Frommer, 2011; Klein et al., 2003b; Marshall, 2010), and in fact vulnerability can be considered complimentary to resilience. Therefore, vulnerability assessment retains relevance within climate change resilience research.

The enhancement of resilience and capacity-building are often considered prerequisites for the management of climate change risks and for the reduction of vulnerability to these risks (O'Brien et al., 2006; Robledo et al., 2004). Additionally, resilience deals with systems, while vulnerability tends to focus on more specific entities (social groups, crops, species, etc.) – a systemic as opposed to actor-oriented approach (Miller et al., 2010). As a result, resilience represents a more holistic approach and presents a (potentially) more positive interpretation of climate change impacts, allowing for a focus on opportunity (Miller et al., 2010).

Adaptation and adaptive capacity

Adaptation is understood as the action or process of change and is associated with adaptive capacity, which is understood as the potential to adapt and to mobilize elements, as a set of preconditions enabling individuals or groups to respond to climate change, or as the measure of the culture and dynamics of human groups allowing them to make decisions in a timely and appropriate manner (Adger et al., 2011; Beermann, 2011; O'Brien et al., 2006). Adaptation and adaptive capacity are considered important determinants of resilience (Klein et al., 2003b; Myers et al., 2012; Tompkins and Adger, 2004). A resilience framework lends a more holistic vision to the evaluation of adaptive capacity and allows for a more complete analysis of adaptation as a process (Nelson et al., 2007).

Transformation

Although transformation and transformability have been discussed by some authors of SES literature for years, only recently have these concepts seen widespread incorporation into this literature and as fundamentally related to resilience (Walker et al., 2005; Folke et al., 2010). This resonates with the results of our systematic review, which do not show an overall (relative) tendency for the inclusion of transformation as a capacity fundamental to resilience. Nevertheless, in literature published after the period reviewed by this study (post-2012), as well as within recent international academic discussions (for example, Human Security Conference, Oslo, 2012; Resilience 2014 Conference, Montpellier), transformation has increasingly been included within resilience conceptualizations.

Resilience and transformation are related and both involve the process of adaptation, but the result of this adaptation is not the same. When a system transforms, it adapts by changing its basic structure and function (Walker et al., 2006). On the other hand, a resilient system adapts but conserves its basic structure and function, and, therefore, identity.

In early discussions, resilience conceptualizations tended to focus on persisting and maintaining structure, function, and identity; generally, this meant that the basic structure of a system should not change. This understanding has evolved into a more flexible definition of resilience which incorporates transformation; a system may undergo change when it presents a poor underlying condition or is trapped in an undesirable state – undesirable structure and function (Walker et al., 2006). In this way, transformability and adaptability have come to be recognized as concepts distinguishing between different types of resilience (Folke et al., 2010). Olsson et al. (2014) clearly illustrate this distinction: "Transformability refers to the social-ecological capacities that enable shifts from one regime to another, and adaptability refers to the capacities to deal with change and stay within a regime". The identification of more or less desired states often represents a value judgment and inevitably introduces subjectivity; generally this is a decision made by and between those who interact with a given system (investigators, policy makers, or decision-makers) and internal actors.

5. Conclusions

This work illustrates the extent of use of the resilience term within the climate change field in recent years. It is important to recognize the value of the diversity and variety of existing resilience conceptualizations; nevertheless, this diversity also has the potential to create confusion, especially in attempts at practical application by stakeholders, decision makers and other social actors. This confusion can distract researchers or policy makers when the term appears too ambiguous for application. One of the fundamental contributions of this paper represents an attempt to structure and catalogue diverse understandings of resilience, by highlighting and illustrating this diversity and focusing on managing diversity and complexity.

The systematic review helped us identify a basis of divergences amongst existing resilience conceptualizations and clarify tendencies. We propose a concrete approach for structuring resilience conceptualization and the identification of conceptual basis, determinants, and attributes of resilience.

With our systematic review we were able to unite a large amount of disperse information from various disciplines to present it in a way that is easier to understand and more easily applied: the Resilience Wheel. The inclusion of determinants, attributes, and supporting theoretical assumptions for resilience building within our resilience framework lends these concepts the importance they deserve. The Resilience Wheel provides flexibility for contextualization within distinct realities via the selection of determinants and attributes for a given application and allows for the explicit incorporation of the advances of resilience theory – emerging from multiple disciplinary perspectives – to applications within different cases.

Resilience theory represents one option for confronting climate change, providing a holistic, locally-focused approach, which incorporates social and ecological components as well as temporal and spatial considerations, and, most importantly, providing concrete tools for confronting the uncertainty surrounding climate change (for example, via the incorporation of multiple actors and the focus on local and existing capacities, both social and ecological). This uncertainty represents one of the greatest challenges posed by climate change.

Incorporating diverse perspectives to address resilience represents one of the greatest challenges for policy makers and decision makers, but is nevertheless fundamental for advancing along this path. Additional challenges in the implementation of the resilience approach involve the need for the devolution of power to communities and other social actors beyond government agencies in order to enable self-organization, a diversity of actors, and citizen participation. In the same way, in the pursuit of attributes such as redundancy, planning and response, the challenge arises of improving public management and moving away from the status quo to achieve effective response to a changing climate.

Resilience as a concept has received much criticism related to the ambiguity of its definitions and conceptualizations (Frommer, 2011; Sovacool et al., 2012; Walker et al., 2002); it is not easily operational or applicable for policy and management in the context of climate change (Amundsen, 2012; Boyd et al., 2008; Maynard et al., 2010). Directing future investigative and political initiatives requires a clear understanding of the current knowledge surrounding a topic. The Resilience Wheel addresses this need to advance the operationalization of resilience, and represents one approach for implementing resilience assessment or resilience building, which should necessarily be undertaken by multiple actors in order to advance beyond a purely theoretical interpretation.

References

Adger, W.N. (2000) Social and ecological resilience: are they related? Progress in Human Geography 24, 347-364.

Adger, W.N., Brown, K., Nelson, D.R., Berkes, F., Eakin, H., Folke, C., Galvin, K., Gunderson, L., Goulden, M., O'Brien, K., Ruitenbeek, J., Tompkins, E.L. (2011) Resilience implications of policy responses to climate change. Wiley Interdisciplinary Reviews: Climate Change 2, 757-766.

Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R., Rockstrom, J. (2005) Social-ecological resilience to coastal disasters. Science 309, 1036-1039.

Aldunce, P., Beilin, R., Handmer, J., Howden, M. (2014) Framing disaster resilience: The implications of the diverse conceptualisations of “bouncing back”. Disaster Prevention and Management 23, 252-270.

Aldunce, P., Beilin, R., Howden, M., Handmer, J., (2015) Resilience for disaster risk management in a changing climate: practitioners’ frames and practices. Global Environmental Change 30, 1-11.

Alliance, R. (2010) Assessing resilience in social-ecological systems: workbook for practitioners. Version 2, 54.

Amundsen, H. (2012) Illusions of resilience? An analysis of community responses to change in northern Norway. Ecology and Society 17.

Anderies, J.M., Folke, C., Walker, B., Ostrom, E. (2013) Aligning key concepts for global change policy: Robustness, resilience, and sustainability. Ecology and Society 18, 8.

Bahadur, A., Ibrahim, M., Tanner, T., (2010) The resilience renaissance? Unpacking of resilience for tackling climate change and disasters Strengthening Climate Resilience Discussion Paper 1. Institute of Development Studies, Brighton.

Barnett, J. (2001) Adapting to climate change in Pacific Island Countries: the problem of uncertainty. World Development 29, 977-993.

Beermann, M. (2011) Linking corporate climate adaptation strategies with resilience thinking. Journal of Cleaner Production 19, 836-842.

Berkes, F. (2007) Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. Natural Hazards 41, 283-295.

Berrang-Ford, L., Ford, J.D., Paterson, J. (2011) Are we adapting to climate change? Global Environmental Change 21, 25-33.

Bodin, P., Wiman, B. (2004) Resilience and other stability concepts in ecology: notes on their origin, validity, and usefulness. ESS Bulletin, 33-43.

Boon, H.J., Cottrell, A., King, D., Stevenson, R.B., Millar, J. (2012) Bronfenbrenner's bioecological theory for modelling community resilience to natural disasters. Natural Hazards 60, 381-408.

Boyd, E., Osbahr, H., Ericksen, P.J., Tompkins, E.L., Lemos, M.C., Miller, F. (2008) Resilience and 'Climatizing' development: Examples and policy implications. Development 51, 390-396.

Bravo, M.T. (2009) Voices from the sea ice: the reception of climate impact narratives. Journal of Historical Geography 35, 256-278.

Brown, K. (2013) Global environmental change I: A social turn for resilience? Progress in Human Geography.

Brown, K., Westaway, E., (2011) Agency, capacity, and resilience to environmental change: lessons from human development, well-being, and disasters, in: Gadgil, A., Liverman, D.M. (Eds.), Annual Review of Environment and Resources, pp. 321-342.

Buckle, P., (2006) Assessing social resilence, in: Paton, D., Johnston, D. (Eds.), Disaster resilience: an integrated approach. Charles C. Thomas Publisher, Springfield, Illinois, pp. 88-104.

Côté, I.M., Darling, E.S. (2010) Rethinking ecosystem resilience in the face of climate change. PLoS Biology 8.
Cote, M., Nightingale, A.J. (2012) Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. Progress in Human Geography 36, 475-489.
Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J. (2008) A place-based model for understanding community resilience to natural disasters. Global Environmental Change - Human and Policy Dimensions 18, 598-606.
Chenoweth, L., Stehlik, D. (2001) Building resilient communities: social work practice and rural Queensland. Australian Social Work 54, 47-54.
da Silva, J., Kernaghan, S., Luque, A. (2012) A systems approach to meeting the challenges of urban climate change. International Journal of Urban Sustainable Development 4, 125-145.
DFID Department for International Development, (2009) Eliminating world poverty: building our common future, H.M. Government, The Stationary Office, London, p. 154.
Djalante, R., Thomalla, F. (2011) Community resilience to natural hazards and climate change: a review of definitions and operational frameworks. Asian Journal of Environment and Disaster Management (AJEDM) 3, 339-355.
Downes, B.J., Miller, F., Barnett, J., Glaister, A., Ellemor, H. (2013a) How do we know about resilience? An analysis of empirical research on resilience, and implications for interdisciplinary praxis. Environmental Research Letters 8, 014041.
Downes, B.J., Miller, F., Barnett, J., Glaister, A., Ellemor, H. (2013b) How do we know about resilience? An analysis of empirical research on resilience, and implications for interdisciplinary praxis. Environmental Research Letters 8.
Ebi, K.L. (2011) Resilience to the health risks of extreme weather events in a changing climate in the United States. International Journal of Environmental Research and Public Health 8, 4582-4595.
Egeland, B., Carlson, E., Sroufe, L.A. (1993) Resilience as process. Development and Psychopathology 5, 517-528.
Folke, C. (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change 16, 253-267.
Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., Rockström, J. (2010) Resilience thinking: Integrating resilience, adaptability and transformability. Ecology and Society 15.
Folke, C., Hahn, T., Olsson, P., Norberg, J. (2005) Adaptive governance of social-ecological systems. Annual Review of Environment and Resources 30, 441-473.
Ford, J.D., Berrang-Ford, L., Paterson, J. (2011) A systematic review of observed climate change adaptation in developed nations. Climatic Change 106, 327-336.
Frommer, B. (2011) Climate change and the resilient society: utopia or realistic option for German regions? Natural Hazards 58, 85-101.
Gaillard, J.C. (2010) Vulnerability, capacity and resilience: perspectives for climate and development policy. Journal of International Development 22, 218-232.
Godschalk, D.R. (2003) Urban hazard mitigation: creating resilient cities. Natural Hazards Review 4, 136-143.
Gordon, J. (1978) Structures. Penguin Books, Harmondsworth.
Gunderson, L., Folke, C., (2005) Resilience - now more than ever (editorial), Ecology and Society & Natural Resources.
Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., Nooteboom, S., Bergsma, E. (2010) The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. Environmental Science & Policy 13, 459-471.

Holling, C. (1961) Principles of insect predation. Annual Review of Entomology 6, 163-182.
Holling, C. (1973) Resilience and stability of ecological systems. Annual Review Ecological Systems 4, 1-23.
Holling, C., Schindler, D., Walker, B., Roughgarden, J., (1995) Biodiversity in the functioning of ecosystems: an ecological synthesis, in: Perrings, C., Maler, K., Folke, C., Holling, C., Jansson, B. (Eds.), Biodiversity loss: economic and ecological issues. Cambridge University Press, Cambridge, pp. 44-83.
Ibarrarán, M.E., Malone, E.L., Brenkert, A.L. (2010) Climate change vulnerability and resilience: Current status and trends for Mexico. Environment, Development and Sustainability 12, 365-388.
Jacso, P. (2005) As we may search-Comparison of major features of the Web of Science, Scopus, and Google Scholar citation-based and citation-enhanced databases. CURRENT SCIENCE-BANGALORE- 89, 1537.
Johnson, J.L., Wiechelt, S.A. (2004) Introduction to the special issue on resilience. Substance Use & Misuse 39, 657-670.
Keim, M.E. (2008) Building Human Resilience. The Role of Public Health Preparedness and Response As an Adaptation to Climate Change. American Journal of Preventive Medicine 35, 508-516.
Klein, R., Nicholls, R., Thomalla, F. (2003a) Resilience to natural hazards: how useful is the concept? Environmental Hazards 5, 35-45.
Klein, R.J.T., Nicholls, R.J., Thomalla, F. (2003b) Resilience to natural hazards: How useful is this concept? Environmental Hazards 5, 35-45.
Lewontin, R., (1969) The meaning of stability: diversity and stability of ecological systems, Brookhaven symposia in biology no 22, Brookhaven, New York.
Linnenluecke, M.K., Griffiths, A. (2012) Assessing organizational resilience to climate and weather extremes: Complexities and methodological pathways. Climatic Change 113, 933-947.
Liu , J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., Taylor, W.W. (2007) Complexity of coupled human and natural systems. Science 317, 1513-1516.
Manyena, S.B. (2006) The concept of resilience revisited. Disasters 30, 433-450.
Marshall, N.A. (2010) Understanding social resilience to climate variability in primary enterprises and industries. Global Environmental Change 20, 36-43.
Masten, A.S., Best, K.M., Garmezy, N. (1990) Resilience and development: contributions from the study of children who overcome adversity. Development and Psychopathology 2, 425-444.
May, R. (1972) Will a large complex ecosystem be stable? Nature 238, 413-414.
Maynard, J.A., Marshall, P.A., Johnson, J.E., Harman, S. (2010) Building resilience into practical conservation: Identifying local management responses to global climate change in the southern Great Barrier Reef. Coral Reefs 29, 381-391.
McClanahan, T.R., Donner, S.D., Maynard, J.A., MacNeil, M.A., Graham, N.A.J., Maina, J., Baker, A.C., Alemu I, J.B., Beger, M., Campbell, S.J., Darling, E.S., Eakin, C.M., Heron, S.F., Jupiter, S.D., Lundquist, C.J., McLeod, E., Mumby, P.J., Paddack, M.J., Selig, E.R., van Woesik, R. (2012) Prioritizing Key Resilience Indicators to Support Coral Reef Management in a Changing Climate. PLoS ONE 7.
Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., Walker, B., Birkmann, J., van der Leeuw, S., Rockström, J. (2010) Resilience and vulnerability: complementary or conflicting concepts. Ecology and Society 15, 11.
Moser, S., (2008) Resilience in the face of global environmental change. CARRI Research report 2, Oak Ridge, p. 44.

Myers, S.A., Blackmore, M.J., Smith, T.F., Bill Carter, R.W. (2012) Climate change and stewardship: Strategies to build community resilience in the Capricorn Coast. Australasian Journal of Environmental Management 19, 164-181.
Nelson, D.R., Adger, W.N., Brown, K. (2007) Adaptation to environmental change: contributions of a resilience framework. Annual Review of Environment and Resources 32, 395.
Norris, F.H., Stevens, S.P., Pfefferbaum, B., Wyche, K.F., Pfefferbaum, R.L. (2008) Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. American Journal of Community Psychology 41, 127-150.
Norris, F.H., Tracy, M., Galea, S. (2009) Looking for resilience: understanding the longitudinal trajectories of responses to stress. Social Science Medicine 68, 2190-2198.
O'Brien, G., O'Keefe, P., Gadema, Z., Swords, J. (2010) Approaching disaster management through social learning. Disaster Prevention and Management 19, 498-508.
O'Brien, G., O'Keefe, P., Rose, J., Wisner, B. (2006) Climate change and disaster management. Disasters 30, 64-80.
Olwig, M.F. (2012) Multi-sited resilience: The mutual construction of "local" and "global" understandings and practices of adaptation and innovation. Applied Geography 33, 112-118.
Olsson, P., Galaz, V., Boohstra, W., (2014) Sustainability transformations: a resilience perspective. Ecology and Society 19, 1.
Pfefferbaum, B., Reissman, D., Pfefferbaum, R., Klomp, R., Gurwitch, R., (2005) Building resilience to mass trauma events, in: Doll, L., Bonzo, S., Mercy, J., Sleet, D. (Eds.), Handbook on injury and violence prevention interventions. Kluwer Academic Publishers, New York, pp. 347-358.
Resilience Alliance, (2012) Resilience Alliance: key concepts.
Robledo, C., Fischler, M., Patino, A. (2004) Increasing the resilience of hillside communities in Bolivia: Has vulnerability to climate change been reduced as a result of previous sustainable development cooperation? Mountain Research and Development 24, 14-18.
Roman, C.E., Lynch, A.H., Dominey-Howes, D. (2010) Uncovering the essence of the climate change adaptation problem—A case study of the tourism sector at Alpine Shire, Victoria, Australia. Tourism and Hospitality Planning & Development 7, 237-252.
Rosenzweig, M. (1971) Paradox of enrichment: destabilization of exploitation ecosystems in ecological time. Science 171, 385-387.
Schwarz, A.M., Béné, C., Bennett, G., Boso, D., Hilly, Z., Paul, C., Posala, R., Sibiti, S., Andrew, N. (2011) Vulnerability and resilience of remote rural communities to shocks and global changes: Empirical analysis from Solomon Islands. Global Environmental Change 21, 1128-1140.
Sovacool, B.K., D'Agostino, A.L., Meenawat, H., Rawlani, A. (2012) Expert views of climate change adaptation in least developed Asia. Journal of Environmental Management 97, 78-88.
Tompkins, E.L., Adger, W.N. (2004) Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society 9.
Van der Leeuw, S., Leygonie, E., (2000) A long-term perspective on resilience in socio-natural systems, Workshop on system shocks - system resilience, Abisko, Sweden, pp. 22-26.
Vogel, C., Moser, S.C., Kasperson, R.E., Dabelko, G.D. (2007) Linking vulnerability, adaptation, and resilience science to practice: pathways, players, and partnerships. Global Environmental Change - Human and Policy Dimensions 17, 349-364.
Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G.D., Pritchard, R. (2002) Resilience management in social-

ecological systems: A working hypothesis for a participatory approach. Ecology and Society 6.
Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., Schultz, L. (2006) A handful of heuristics and some propositions for understanding resilience in social-ecological systems. Ecology and Society 11, 13.
Walker, B., Salt, D. (2006) Resilience thinking: how can landscapes and communities absorb disturbance and maintain function? Island Press, Washington, DC.
Walker, R., Hassall, J., Chaplin, S., Congues, J., Bajayo, R., Mason, W. (2011) Health promotion interventions to address climate change using a primary health care approach: a literature review. Health promotion journal of Australia : official journal of Australian Association of Health Promotion Professionals 22 Spec No, S6-12.
Waller, M.A. (2001) Resilience in ecosystemic context: evolution of the concept. American Journal of Orthopsychiatry 71, 290-297.
Watson, R.T., Albritton, D.L. (2001) Climate change 2001: Synthesis report: Third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

ANNEX 1: REVIEWED DOCUMENTS

ID#	YEAR	AUTHOR(S)	TITLE	JOURNAL	COUNT
P1	2000	Troadec, J. P.	Adaptation opportunities to climate variability and change in the exploitation and utilisation of marine living resources	Environmental Monitoring and Assessment	1
P2	2001	Barnett, J.	Adapting to climate change in Pacific Island countries: The problem of uncertainty	World Development	2
P3	2001	Berkes, F., Jolly, D.	Adapting to climate change: Social-ecological resilience in a Canadian western arctic community	Conservation Ecology	3
P4	2001	Noss, R. F.	Beyond kyoto: Forest management in a time of rapid climate change	Conservation Ecology	4
P6	2002	McClanahan, T., Polunin, N., Done, T.	Ecological states and the resilience of coral reefs	Ecology and Society	5
P7	2002	Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D., Pritchard, R.	Resilience management in social-ecological systems: A working hypothesis for a participatory approach	Ecology and Society	6
P8	2003	Fowler, H. J., Kilsby, C. G., O'Connell, P. E.	Modeling the impacts of climatic change and variability on the reliability, resilience, and vulnerability of a water resource system	Water Resources Research	7
P9	2003	Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nyström, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B., Roughgarden, J.	Climate change, human impacts, and the resilience of coral reefs	Science	8
P10	2003	Klein, R. J. T.,Nicholls, R. J.,Thomalla, F.	Resilience to natural hazards: How useful is this concept?	Environmental Hazards	9
P11	2003	Sergio, F.	From individual behaviour to population pattern: Weather-dependent foraging and breeding performance in black kites	Animal Behaviour	10
P12	2003	West, J. M.,Salm, R. V.	Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management	Conservation Biology	11

P13	2004	Kriegler, E.,Bruckner, T.	Sensitivity analysis of emissions corridors for the 21st century	Climatic Change	12
P14	2004	Lloret, F.,Siscart, D.,Dalmases, C.	Canopy recovery after drought dieback in holm-oak Mediterranean forests of Catalonia (NE Spain)	Global Change Biology	13
P15	2004	Robledo, C.,Fischler, M.,Patino, A.,	Increasing the resilience of hillside communities in Bolivia: Has vulnerability to climate change been reduced as a result of previous sustainable development cooperation?	Mountain Research and Development	14
P16	2004	Tompkins, E. L.,Adger, W. N.	Does adaptive management of natural resources enhance resilience to climate change?	Ecology and Society	15
P17	2005	Brenkert, A. L.,Malone, E. L.	Modeling vulnerability and resilience to climate change: A case study of India and Indian states	Climatic Change	16
P18	2005	Hutyra, L. R.,Munger, J. W.,Nobre, C. A.,Saleska, S. R.,Vieira, S. A.,Wofsy, S. C.	Climatic variability and vegetation vulnerability in Amazonia	Geophysical Research Letters	17
P19	2005	Tompkins, E. L.	Planning for climate change in small islands: Insights from national hurricane preparedness in the Cayman Islands	Global Environmental Change	18
P20	2006	O'Brien, G.,O'Keefe, P.,Rose, J.,Wisner, B.	Climate change and disaster management	Disasters	19
P21	2006	Young, K. R.,Lipton, J. K.	Adaptive governance and climate change in the tropical highlands of Western South America	Climatic Change	20
P22	2007	Done, T.,Turak, E.,Wakeford, M.,DeVantier, L.,McDonald, A.,Fisk, D.	Decadal changes in turbid-water coral communities at Pandora Reef: Loss of resilience or too soon to tell?	Coral Reefs	21
P23	2007	Endfield, G. H.	Archival explorations of climate variability and social vulnerability in colonial Mexico	Climatic Change	22
P24	2007	Forbes, B. C.	Equity, vulnerability and resilience in social-ecological systems: a contemporary example from the Russian Arctic		23
P25	2007	Millar, C. I.,Stephenson, N. L.,Stephens, S. L.	Climate change and forests of the future: Managing in the face of uncertainty	Ecological Applications	24
P26	2007	Muller, M.	Adapting to climate change: Water management for urban resilience	Environment and Urbanization	25

P27	2007	Rivington, M.,Matthews, K. B.,Bellocchi, G.,Buchan, K.,Stöckle, C. O.,Donatelli, M.	An integrated assessment approach to conduct analyses of climate change impacts on whole-farm systems	Environmental Modelling and Software	26
P28	2007	White, I.,Falkland, T.,Metutera, T.,Metai, E.,Overmars, M.,Perez, P.,Dray, A.,Falkland, A. C.	Climatic and human influences on groundwater in low atolls	Vadose Zone Journal	27
P29	2008	Alongi, D. M.	Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change	Estuarine, Coastal and Shelf Science	28
P30	2008	Birrell, C. L.,McCook, L. J.,Willis, B. L.,Diaz-Pulido, G. A.	Effects of benthic algae on the replenishment of corals and the implications for the resilience of coral reefs		29
P31	2008	Boyd, E.,Osbahr, H.,Ericksen, P. J.,Tompkins, E. L.,Lemos, M. C.,Miller, F.	Resilience and 'Climatizing' development: Examples and policy implications	Development	30
P32	2008	Ebi, K. L.,Semenza, J. C.	Community-Based Adaptation to the Health Impacts of Climate Change	American Journal of Preventive Medicine	31
P33	2008	Evans, G. R.	Transformation from "Carbon Valley" to a "Post-Carbon Society" in a climate change hot spot: The coalfields of the Hunter Valley, New South Wales, Australia	Ecology and Society	32
P34	2008	Hess, J. J.,Malilay, J. N.,Parkinson, A. J.	Climate Change. The Importance of Place	American Journal of Preventive Medicine	33
P35	2008	Jerneck, A.,Olsson, L.	Adaptation and the poor: Development, resilience and transition	Climate Policy	34
P36	2008	Keim, M. E.	Building Human Resilience. The Role of Public Health Preparedness and Response As an Adaptation to Climate Change	American Journal of Preventive Medicine	35
P37	2008	Malone, E. L.,Brenkert, A. L.	Uncertainty in resilience to climate change in India and Indian states	Climatic Change	36
P38	2008	Middleton, J.	Environmental health, climate chaos and resilience	Medicine, conflict, and survival	37
P39	2008	Moore, S. E.,Huntington, H. P.	Arctic marine mammals and climate change: Impacts and resilience	Ecological Applications	38
P40	2008	Nitschke, C. R.,Innes, J. L.	A tree and climate assessment tool for modelling ecosystem response to climate change	Ecological Modelling	39
P41	2008	Pittock, J.,Hansen, L. J.,Abell, R.	Running dry: Freshwater biodiversity, protected areas and climate change	Biodiversity	40

P42	2008	Schroder, M.,James, G.,Marchment, A.	Coordinated regeneration programs in coastal vegetation on the Tomaree Peninsula - A decade of bitou bush control	Plant Protection Quarterly	41
P44	2009	Aguilar, M. Y.,Pacheco, T. R.,Tobar, J. M.,Quinonez, J. C.	Vulnerability and adaptation to climate change of rural inhabitants in the central coastal plain of El Salvador	Climate Research	42
P45	2009	Bravo, M. T.	Voices from the sea ice: the reception of climate impact narratives	Journal of Historical Geography	43
P46	2009	Carilli, J. E.,Norris, R. D.,Black, B. A.,Walsh, S. M.,McField, M.	Local stressors reduce coral resilience to bleaching	PLoS ONE	44
P47	2009	Diaz-Pulido, G.,McCook, L. J.,Dove, S.,Berkelmans, R.,Roff, G.,Kline, D. I.,Weeks, S.,Evans, R. D.,Williamson, D. H.,Hoegh-Guldberg, O.	Doom and Boom on a Resilient Reef: Climate Change, Algal Overgrowth and Coral Recovery	PLoS ONE	45
P48	2009	Lomas, K. J., Ji, Y.	Resilience of naturally ventilated buildings to climate change: Advanced natural ventilation and hospital wards	Energy and Buildings	46
P49	2009	McLeod, E.,Salm, R.,Green, A.,Almany, J.	Designing marine protected area networks to address the impacts of climate change	Frontiers in Ecology and the Environment	47
P50	2009	O'Brien, K.,Hayward, B.,Berkes, F.	Rethinking social contracts: Building resilience in a changing climate	Ecology and Society	48
P51	2009	Peter, C.,De Lange, W.,Musango, J. K.,April, K.,Potgieter, A.	Applying Bayesian modelling to assess climate change effects on biofuel production	Climate Research	49
P53	2009	Saavedra, C.,Budd, W. W.	Climate change and environmental planning: Working to build community resilience and adaptive capacity in Washington State, USA	Habitat International	50
P54	2009	West, J. M.,Julius, S. H.,Kareiva, P.,Enquist, C.,Lawler, J. J.,Petersen, B.,Johnson, A. E.,Shaw, M. R.	U.S. natural resources and climate change: Concepts and approaches for management adaptation	Environmental Management	51
P55	2010	Bloetscher, F., Meeroff, D.E., Heimlich, B.N., Randolph Brown, A., Bayler, D., Loucraft, M.	Improving resilience against the effects of climate change	Journal / American Water Works Association	52
P56	2010	Bosher, L.	Urban futures: Energy crises and sporadic responses	Building Research and Information	53
P57	2010	Bunce, M.,Brown, K.,Rosendo, S.	Policy misfits, climate change and cross-scale vulnerability in coastal Africa: how development projects undermine resilience	Environmental Science and Policy	54

P58	2010	Burch, S.	In pursuit of resilient, low carbon communities: An examination of barriers to action in three Canadian cities	Energy Policy	55
P60	2010	Cannon, T.,Müller-Mahn, D.	Vulnerability, resilience and development discourses in context of climate change	Natural Hazards	56
P61	2010	Carroll, C.,Dunk, J. R.,Moilanen, A.	Optimizing resiliency of reserve networks to climate change: Multispecies conservation planning in the Pacific Northwest, USA	Global Change Biology	57
P62	2010	Chapin Iii, F. S.,McGuire, A. D.,Ruess, R. W.,Hollingsworth, T. N.,Mack, M. C.,Johnstone, J. F.,Kasischke, E. S.,Euskirchen, E. S.,Jones, J. B.,Jorgenson, M. T.,Kielland, K.,Kofinas, G. P.,Turetsky, M. R.,Yarie, J.,Lloyd, A. H.,Taylor, D. L.	Resilience of Alaska's boreal forest to climatic change	Canadian Journal of Forest Research	58
P64	2010	Côté, I. M.,Darling, E. S.	Rethinking ecosystem resilience in the face of climate change	PLoS Biology	59
P65	2010	Crabbe, M. J. C.	Coral ecosystem resilience, conservation and management on the reefs of Jamaica in the face of anthropogenic activities and climate change	Diversity	60
P66	2010	Daccache, A.,Weatherhead, K.,Lamaddalena, N.	Climate change and the performance of pressurized irrigation water distribution networks under Mediterranean conditions: Impacts and adaptations	Outlook on Agriculture	61
P68	2010	Frazier, T. G.,Wood, N.,Yarnal, B.	Stakeholder perspectives on land-use strategies for adapting to climate-change-enhanced coastal hazards: Sarasota, Florida	Applied Geography	62
P70	2010	Howard, G.,Katrina, C.,Pond, K.,Brookshaw, A.,Hossain, H.,Bartram, J.	Securing 2020 vision for 2030: Climate change and ensuring resilience in water and sanitation services	Journal of Water and Climate Change	63
P71	2010	Ibarrarán, M. E.,Malone, E. L.,Brenkert, A. L.	Climate change vulnerability and resilience: Current status and trends for Mexico	Environment, Development and Sustainability	64
P72	2010	Jorgenson, M.T., Romanovsky, V., Harden, J., Shur, Y., O´Donnell, J., Schuur, E.A.G., Kanevskiy, M., Marchenko, S.	Resilience and vulnerability of permafrost to climate change	Canadian Journal of Forest Research	65

P74	2010	Kennedy, D.,Stocker, L.,Burke, G.	Australian local government action on climate change adaptation: Some critical reflections to assist decision-making	Local Environment	66
P75	2010	Lambert, E.,Hunter, C.,Pierce, G. J.,MacLeod, C. D.	Sustainable whale-watching tourism and climate change: Towards a framework of resilience	Journal of Sustainable Tourism	67
P76	2010	Lemelin, H.,Matthews, D.,Mattina, C.,McIntyre, N.,Johnston, M.,Koster, R.,Weenusk First Nation At, Peawanuck	Climate change, wellbeing and resilience in the Weenusk First Nation at Peawanuck: the Moccasin Telegraph goes global	Rural and remote health	68
P77	2010	Linnenluecke, M., Griffiths, A.	Beyond adaptation: Resilience for business in light of climate change and weather extremes	Business and Society	69
P79	2010	Marshall, N. A.	Understanding social resilience to climate variability in primary enterprises and industries	Global Environmental Change	70
P80	2010	Maynard, J. A.,Marshall, P. A.,Johnson, J. E.,Harman, S.	Building resilience into practical conservation: Identifying local management responses to global climate change in the southern Great Barrier Reef	Coral Reefs	71
P81	2010	McBean, G.,Rodgers, C.	Climate hazards and disasters: The need for capacity building	Wiley Interdisciplinary Reviews: Climate Change	72
P82	2010	Miller, K.,Charles, A.,Barange, M.,Brander, K.,Gallucci, V. F.,Gasalla, M. A.,Khan, A.,Munro, G.,Murtugudde, R.,Ommer, R. E.,Perry, R. I.	Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science	Progress in Oceanography	73
P83	2010	Montoya, J. M.,Raffaelli, D.	Climate change, biotic interactions and ecosystem services	Philosophical Transactions of the Royal Society B: Biological Sciences	74
P84	2010	Nuorteva, P.,Keskinen, M.,Varis, O.	Water, livelihoods and climate change adaptation in the tonle sap lake area, Cambodia: Learning from the past to understand the future	Journal of Water and Climate Change	75
P85	2010	O'Brien, G.,O'Keefe, P.	Resilient responses to climate change and variability: A challenge for public policy	International Journal of Public Policy	76
P86	2010	Osbahr, H.,Twyman, C.,Adger, W. N.,Thomas, D. S. G.	Evaluating Successful Livelihood Adaptation to Climate Variability and change in Southern Africa	Ecology and Society	77
P87	2010	Prato, T.	Erratum: Sustaining Ecological Integrity with Respect to Climate Change: A Fuzzy Adaptive Management Approach (Environmental Management (2010) 45:1344-1351)	Environmental Management	78

P88	2010	Seo, S. N.	Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture	Food Policy	79
P89	2010	Trudgill, S.,Jeffery, A.,Parker, J.	Climate change and the resilience of the domestic lawn	Applied Geography	80
P90	2010	Tschakert, P.,Dietrich, K. A.	Anticipatory learning for climate change adaptation and resilience	Ecology and Society	81
P91	2010	Wardekker, J. A.,de Jong, A.,Knoop, J. M.,van der Sluijs, J. P.	Operationalising a resilience approach to adapting an urban delta to uncertain climate changes	Technological Forecasting and Social Change	82
P92	2010	Wilbanks, T. J.,Kates, R. W.	Beyond adapting to climate change: Embedding adaptation in responses to multiple threats and stresses	Annals of the Association of American Geographers	83
P95	2011	Adger, W. N.,Brown, K.,Nelson, D. R.,Berkes, F.,Eakin, H.,Folke, C.,Galvin, K.,Gunderson, L.,Goulden, M.,O'Brien, K.,Ruitenbeek, J.,Tompkins, E. L.	Resilience implications of policy responses to climate change	Wiley Interdisciplinary Reviews: Climate Change	84
P96	2011	Anthony, K. R. N.,Maynard, J. A.,Diaz-Pulido, G.,Mumby, P. J.,Marshall, P. A.,Cao, L.,Hoegh-Guldberg, O.	Ocean acidification and warming will lower coral reef resilience	Global Change Biology	85
P97	2011	Antrobus, D.	Smart green cities: From modernization to resilience?	Urban Research and Practice	86
P94	2011	Aral, M.M.	Resilience analysis of climate change effects on water quality and health	NATO Science for Peace and Security Series C: Environmental Security	87
P98	2011	Ayers, J., Kaur, N., Anderson, S.	Negotiating Climate Resilience in Nepal	IDS Bulletin	88
P99	2011	Azam, M.M.	Climate change resilience and technology transfer: The role of intellectual property	Nordic Journal of International Law	89
P100	2011	Beermann, M.	Linking corporate climate adaptation strategies with resilience thinking	Journal of Cleaner Production	90
P101	2011	Djordjević, S.,Butler, D.,Gourbesville, P.,Mark, O.,Pasche, E.	New policies to deal with climate change and other drivers impacting on resilience to flooding in urban areas: The CORFU approach	Environmental Science and Policy	91
P102	2011	Ebi, K. L.	Resilience to the health risks of extreme weather events in a changing climate in the United States	International Journal of Environmental Research and Public Health	92
P103	2011	Ervin, J.	Integrating protected areas into climate planning	Biodiversity	93

P104	2011	Frommer, B.	Climate change and the resilient society: Utopia or realistic option for German regions?	Natural Hazards	94
P105	2011	Hall, R.,Winn, J.	Questioning technology in the development of a resilient higher education	E-Learning and Digital Media	95
P106	2011	Houghton, A.	Health impact assessments a tool for designing climate change resilience into green building and planning projects	Journal of Green Building	96
P107	2011	Jackson, T. M.,Hanjra, M. A.,Khan, S.,Hafeez, M. M.	Building a climate resilient farm: A risk based approach for understanding water, energy and emissions in irrigated agriculture	Agricultural Systems	97
P108	2011	Jennings, T. L.	Transcending the adaptation/mitigation climate change science policy debate: Unmasking assumptions about adaptation and resilience	Weather, Climate, and Society	98
P110	2011	Keogh, D.U., Apan, A., Mushtaq, S., King, D., Thomas, M.	Resilience, vulnerability and adaptive capacity of an inland rural town prone to flooding: A climate change adaptation case study of Charleville, Queensland, Australia	Natural Hazards, 59, 699-723	99
P111	2011	Leichenko, R.	Climate change and urban resilience	Current Opinion in Environmental Sustainability	100
P112	2011	Lin, B. B.	Resilience in agriculture through crop diversification: Adaptive management for environmental change	BioScience	101
P113	2011	Mary Kensa, V.,Antoe Jasmine, V.	Managing mangrove for resilience to climatic change	Ecology, Environment and Conservation	102
P114	2011	Meenawat, H.,Sovacool, B. K.	Improving adaptive capacity and resilience in Bhutan	Mitigation and Adaptation Strategies for Global Change	103
P115	2011	Nelson, D. R.	Adaptation and resilience: Responding to a changing climate	Wiley Interdisciplinary Reviews: Climate Change	104
P116	2011	Okvat, H. A.,Zautra, A. J.	Community Gardening: A Parsimonious Path to Individual, Community, and Environmental Resilience	American Journal of Community Psychology	105
P117	2011	Pelling, M.,Manuel-Navarrete, D.	From resilience to transformation: The adaptive cycle in two Mexican urban centers	Ecology and Society	106

P118	2011	Picketts, I. M.,Curry, J.	Climate change adaptation in British Columbia communities: Lessons for planners	International Journal of Sustainable Society	107
P119	2011	Porio, E.	Vulnerability, adaptation, and resilience to floods and climate change-related risks among marginal, riverine communities in Metro Manila	Asian Journal of Social Science	108
P120	2011	Rodriguez, D.,deVoil, P.,Power, B.,Cox, H.,Crimp, S.,Meinke, H.	The intrinsic plasticity of farm businesses and their resilience to change. An Australian example	Field Crops Research	109
P121	2011	Schwarz, A. M.,Béné, C.,Bennett, G.,Boso, D.,Hilly, Z.,Paul, C.,Posala, R.,Sibiti, S.,Andrew, N.	Vulnerability and resilience of remote rural communities to shocks and global changes: Empirical analysis from Solomon Islands	Global Environmental Change	110
P123	2011	Seelig, S.	A master plan for low carbon and resilient housing: The 35ha area in Hashtgerd New Town, Iran	Cities	111
P124	2011	Sgrò, C. M.,Lowe, A. J.,Hoffmann, A. A.	Building evolutionary resilience for conserving biodiversity under climate change	Evolutionary Applications	112
P126	2011	Shaw, K.,Theobald, K.	Resilient local government and climate change interventions in the UK	Local Environment	113
P127	2011	Stephenson, N.L., Millar, C.I.	Climate change: Wilderness's greatest challenge	Park Science 28	114
P128	2011	Walker, R.,Hassall, J.,Chaplin, S.,Congues, J.,Bajayo, R.,Mason, W.	Health promotion interventions to address climate change using a primary health care approach: a literature review	Health promotion journal of Australia : official journal of Australian Association of Health Promotion Professionals	115
P129	2012	Amundsen, H.	Illusions of resilience? An analysis of community responses to change in northern Norway	Ecology and Society	116
P130	2012	Bajayo, R.	Building community resilience to climate change through public health planning	Health Promotion Journal of Australia	117
P131	2012	Boon, H. J.,Cottrell, A.,King, D.,Stevenson, R. B.,Millar, J.	Bronfenbrenner's bioecological theory for modelling community resilience to natural disasters	Natural Hazards	118
P133	2012	Brown, A.,Dayal, A.,Rumbaitis Del Rio, C.	From practice to theory: Emerging lessons from Asia for building urban climate change resilience	Environment and Urbanization	119
P134	2012	Carter, D. L.,Blair, J. M.	High richness and dense seeding enhance grassland restoration establishment but have little effect on drought response	Ecological Applications	120
P135	2012	Conway Sr, G.	How to create resilient agriculture	Appropriate Technology	121

P136	2012	da Silva, J.,Kernaghan, S.,Luque, A.	A systems approach to meeting the challenges of urban climate change	International Journal of Urban Sustainable Development	122
P137	2012	de Stefano, L.,Duncan, J.,Dinar, S.,Stahl, K.,Strzepek, K. M.,Wolf, A. T.	Climate change and the institutional resilience of international river basins	Journal of Peace Research	123
P138	2012	De Vries, F. T.,Liiri, M. E.,Bjørnlund, L.,Bowker, M. A.,Christensen, S.,Setälä, H. M.,Bardgett, R. D.	Land use alters the resistance and resilience of soil food webs to drought	Nature Climate Change	124
P139	2012	Disch, J.,Kay, P.,Mortsch, L.	A resiliency assessment of Ontario's low-water response mechanism: Implications for addressing management of low-water under potential future climate change	Canadian Water Resources Journal	125
P140	2012	Erol, A.,Randhir, T. O.	Climatic change impacts on the ecohydrology of Mediterranean watersheds	Climatic Change	126
P141	2012	Gangolells, M.,Casals, M.	Resilience to increasing temperatures: Residential building stock adaptation through codes and standards	Building Research and Information	127
P142	2012	García-López, J. M.,Allué, C.	A phytoclimatic-based indicator for assessing the inherent responsitivity of the European forests to climate change	Ecological Indicators	128
P143	2012	Gersonius, B.,Ashley, R.,Zevenbergen, C.	The identity approach for assessing socio-technical resilience to climate change: Example of flood risk management for the Island of Dordrecht	Natural Hazards and Earth System Science	129
P144	2012	Ledger, M. E.,Harris, R. M. L.,Armitage, P. D.,Milner, A. M.	Climate Change Impacts on Community Resilience. Evidence from a Drought Disturbance Experiment	Advances in Ecological Research	130
P145	2012	Lewis, K.,Witham, C.	Agricultural commodities and climate change	Climate Policy	131
P146	2012	Linnenluecke, M. K.,Griffiths, A.	Assessing organizational resilience to climate and weather extremes: Complexities and methodological pathways	Climatic Change	132
P147	2012	Lomas, K. J.,Giridharan, R.	Thermal comfort standards, measured internal temperatures and thermal resilience to climate change of free-running buildings: A case-study of hospital wards	Building and Environment	133
P148	2012	Lukac, M.,Gooding, M. J.,Griffiths, S.,Jones, H. E.	Asynchronous flowering and within-plant flowering diversity in wheat and the implications for crop resilience to heat	Annals of Botany	134

P149	2012	Luthe, T.,Wyss, R.,Schuckert, M.	Network governance and regional resilience to climate change: Empirical evidence from mountain tourism communities in the Swiss Gotthard region	Regional Environmental Change	135
P150	2012	McClanahan, T. R.,Donner, S. D.,Maynard, J. A.,MacNeil, M. A.,Graham, N. A. J.,Maina, J.,Baker, A. C.,Alemu I, J. B.,Beger, M.,Campbell, S. J.,Darling, E. S.,Eakin, C. M.,Heron, S. F.,Jupiter, S. D.,Lundquist, C. J.,McLeod, E.,Mumby, P. J.,Paddack, M. J.,Selig, E.R., Van Woesik, R.	Prioritizing Key Resilience Indicators to Support Coral Reef Management in a Changing Climate	PLoS ONE	136
P151	2012	Morecroft, M.D., Crick, H.Q.P., Duffield, S.J., Macgregor, N.A.	Resilience to climate change: Translating principles into practice	Journal of Applied Ecology 49, 547-551	137
P152	2012	Myers, S. A.,Blackmore, M. J.,Smith, T. F.,Bill Carter, R. W.	Climate change and stewardship: Strategies to build community resilience in the Capricorn Coast	Australasian Journal of Environmental Management	138
P153	2012	Olwig, M. F.	Multi-sited resilience: The mutual construction of "local" and "global" understandings and practices of adaptation and innovation	Applied Geography	139
P154	2012	Peterson, T. J.,Western, A. W.,Argent, R. M.	Analytical methods for ecosystem resilience: A hydrological investigation	Water Resources Research	140
P155	2012	Prato, T.	Increasing resilience of natural protected areas to future climate change: A fuzzy adaptive management approach	Ecological Modelling	141
P156	2012	Prober, S. M.,Thiele, K. R.,Rundel, P. W.,Yates, C. J.,Berry, S. L.,Byrne, M.,Christidis, L.,Gosper, C. R.,Grierson, P. F.,Lemson, K.,Lyons, T.,Macfarlane, C.,O'Connor, M. H.,Scott, J. K.,Standish, R. J.,Stock, W. D.,van Etten, E. J. B.,Wardell-Johnson, G.	Facilitating adaptation of biodiversity to climate change: A conceptual framework applied to the world's largest Mediterranean-climate woodland	Climatic Change	142
P157	2012	Roff, G.,Mumby, P. J.	Global disparity in the resilience of coral reefs	Trends in Ecology and Evolution	143
P158	2012	Simane, B.,Zaitchik, B. F.,Mesfin, D.	Building climate resilience in the Blue Nile/Abay Highlands: A framework for action	International Journal of Environmental Research and Public Health	144

P159	2012	Smith, J. W.,Anderson, D. H.,Moore, R. L.	Social Capital, Place Meanings, and Perceived Resilience to Climate Change	Rural Sociology	145
P160	2012	Sovacool, B. K.	Expert views of climate change adaptation in the Maldives	Climatic Change	146
P161	2012	Sovacool, B. K.	Perceptions of climate change risks and resilient island planning in the Maldives	Mitigation and Adaptation Strategies for Global Change	147
P162	2012	Sovacool, B. K.,D'Agostino, A. L.,Meenawat, H.,Rawlani, A.	Expert views of climate change adaptation in least developed Asia	Journal of Environmental Management	148
P163	2012	Sovacool, B. K.,D'Agostino, A. L.,Rawlani, A.,Meenawat, H.	Improving climate change adaptation in least developed Asia	Environmental Science and Policy	149
P132	2012	Tromeur, E., Ménard, R., Bailly, J.B., Soulié, C.	Urban vulnerability and resilience within the context of climate change		150
P164	2012	Turton, S. M.	Securing Landscape Resilience to Tropical Cyclones in Australia's Wet Tropics under a Changing Climate: Lessons from Cyclones Larry (and Yasi)	Geographical Research	151