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ORIGINAL ARTICLE

Climate adaptation heuristics and the science/policy divide

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Abstract The adaptation science enterprise has expanded rapidly in recent years, presumably in response to growth in demand for knowledge that can facilitate adaptation policy and practice. However, evidence suggests such investments in adaptation science have not necessarily translated into adaptation implementation. One potential constraint on adaptation may be the underlying heuristics that are used as the foundation for both adaptation research and practice. Here, we explore the adaptation academic literature with the objective of identifying adaptation heuristics, assessing the extent to which they have become entrenched within the adaptation discourse, and discussing potential weaknesses in their framing that could undermine adaptation efforts. This investigation is supported by a multi-method analysis that includes both a quantitative content analysis of the adaptation literature that evidences the use of adaptation heuristics and a qualitative analysis of the implications of such heuristics for enhancing or hindering the implementation of adaptation. Results demonstrate that a number of heuristic devices are commonly used in both the peer-reviewed adaptation literature as well as within grey literature designed to inform adaptation practitioners. Furthermore, the apparent lack of critical reflection upon the robustness of these heuristics for diverse contexts may contribute to potential cognitive bias with respect to the framing of adaptation by both researchers and practitioners. We discuss this phenomenon by drawing upon heuristic-analytic theory, which has explanatory utility in understanding both the origins of such heuristics as well as the measures that can be pursued toward the co-generation of more robust approaches to adaptation problem-solving.

Keywords Adaptation · Climate change · Heuristics · Cognitive reasoning · Science-policy interface

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1 Introduction

The pursuit of climate adaptation has expanded rapidly in recent years due to increasing awareness of its potential value with respect to reducing societal and ecological vulnerability to current climate variability while managing the risks posed by future climate change (Adger et al. 2007; Adger et al. 2009b; Schipper and Burton 2009a). Whereas once adaptation was viewed as a taboo topic (Pielke et al. 2007; Burton 2009a), adaptation is now being institutionalized at a range of geopolitical scales. Adaptation, and particularly adaptation finance, has become a major subject of debate within international negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), and various funding mechanisms have been developed to support adaptation in developing nations (Schipper and Burton 2009a; Grasso 2010; Hulme et al. 2011; Petherick 2012). National governments of developed nations have also initiated strategic thinking regarding adaptation as represented by the United Kingdom's Climate Change Act (UK Stationary Office 2008), Australia's National Climate Change Adaptation Framework (DCC 2007), and the Obama Administration's Executive Order 13514 (The White House 2009), which requires United States (US) federal agencies to assess and manage the risks posed by climate change to agency missions. Such top down approaches to adaptation are complemented by a broad range of bottom up efforts represented by local/municipal, and state/district adaptation planning (Lindseth 2005; Saavedra and Budd 2009; Dedekorkut et al. 2010; Preston and Kay 2010; Burton and Mustelin 2013; Measham et al. 2011).

This growth in adaptation practice has been accompanied by a concomitant growth in adaptation science, which we define broadly as research that generates knowledge that can inform adaptation and its implementation. Despite such investments, evidence suggests those investments have not necessarily translated into the implementation of adaptation policies and measures that reduce vulnerability (Repetto 2008; Schipper and Burton 2009b; Wilby and Vaughan 2011). Rather, a number of authors have noted that an 'adaptation deficit' exists in both developed and developing nations (Adger et al. 2007; Repetto 2008; Burton 2009a; Moser 2009a). Meanwhile, although anticipatory adaptation is widely cited as a cost-effective approach to managing climate risk, evidence suggests that experience with extreme events in the present day is a more common trigger of adaptation planning (Moench 2009; Næss et al. 2005; Simonsson et al. 2011). In addition, multiple examinations of adaptation planning suggest that investments in adaptation are predominantly focused on non-structural measures as opposed to more substantive actions to reduce vulnerability (Ford et al. 2011; Preston et al. 2011a; Lesnikowski et al. 2013). Hence, institutions are expressing an intention to adapt, but are not necessarily adapting (Berrang-Ford et al. 2011; Ford and Berrang-Ford 2011). The slow pace of adaptation implementation is explained by an expanding academic literature that identifies potential constraints on, and limits to, adaptation (Adger et al. 2007, 2009a; Moser 2009a; Moser and Ekstrom 2010; Measham et al. 2011; Gero et al. 2012). Little of this discussion of constraints and limits, however, questions the underlying assumptions regarding adaptation science and practice and the most effective means by which knowledge can be used to facilitate adaptation.

Core assumptions that guide adaptation may be encapsulated within heuristic devices. Ravetz (1972) suggests that each scientific field develops a set of standardized facts over time that is used to explain the core characteristics and the nature of the issue under scrutiny. When those facts are disseminated into the public sphere (e.g., via publication), they are stripped of nuance and "some important but subtle aspects of the assertions or its objects, are smoothed over or forgotten" (Ravetz 1972, p. 200–201). While this process is necessary (Ravetz 1972), over time these facts become common sense, and are no longer questioned. Such 'rules of thumb' or heuristics are both useful and fundamental in establishing a common practice (Slovic et al. 1982; Kuhn 1996; Evans 2003, 2006; Osman 2004). However, once particular assumptions are established, it becomes increasingly

difficult to recognize which of these are useful in guiding effective practice and which function as potential constraints or cognitive biases. In fact, if such deeply ingrained assumptions are left unexamined and unchallenged, they might continue influencing choices in particular policy pathways even when the practical realities might not warrant such courses of action (Patt 2012). In the context of integrated coastal zone management, Billè (2008, p. 1) calls such spurious assumptions illusions. Similarly, Moser and Dilling (2007) have identified nine myths that are commonly used to explain and justify certain modes of cognitive reasoning and decision-making on how to address climate change.

Given the argument of Ravetz (1972), one would anticipate that, as with other disciplines and arenas of public discourse, the evolution of adaptation would lead to the development and institutionalization of heuristics that distill adaptation knowledge into general principles. While heuristics can play a valuable role in facilitating adaptation, if those heuristics fail to be robust (i.e., applicable for a diversity of adaptation contexts), they have the potential to impede adaptation efforts. Hence, the objectives of the current study were to identify a number of putative adaptation heuristics, assess the extent to which they have become entrenched within the adaptation discourse, and discuss potential weaknesses in their framing that could undermine adaptation research and practice. In pursuing these objectives we first define the concept of an adaptation heuristic and then describe a set of heuristics that we argue are particularly common in the adaptation discourse. We then report the methods and results of a systematic content analysis of the adaptation literature to identify documents containing exemplary language associated with these heuristics, discuss the extent to which they endorse or critique their use, and the implications for adaptation. We conclude by discussing both the theoretical and practical origins of such heuristics and the mechanisms by which they can be rigorously critiqued so they can become a more robust foundation for adaptation discourse.

2 Methods

To explore the manifestation of adaptation heuristics within the adaptation literature, we first defined an adaptation heuristic as a common sense, rule of thumb guiding the conceptual framing of adaptation, the prioritization of adaptation policies and measures, and/or the pathways by which they are implemented. As such, the use of a heuristic device is often characterized by the absence of critical analysis of its validity or relevance. Rather, it is invoked as an appeal to accepted conventional wisdom or as a self-evident truth based upon a priori knowledge and experience. In the context of this definition, we subsequently identified a set of eight putative heuristics based on arguments and criticisms appearing in our own research (Table 1; Preston and Stafford-Smith 2009; Preston 2009; Preston et al. 2011a, b; Preston et al. 2013; Burton and Mustelin 2013; Mustelin et al. 2010, 2013; Mustelin 2013) as well as that of other adaptation researchers (e.g., Burton 2008; Dessai et al. 2009; Hulme et al. 2011). While not a comprehensive list of all heuristic devices that may be used in adaptation research and practice, it reflects a useful starting point for exploring the extent to which different heuristics manifest in the literature and for drawing attention to the role of heuristics in the discourse of climate adaptation. To explore the use of such heuristics in the adaptation literature, we applied a multi-method approach that included both a quantitative content analysis of the adaptation literature as well as a qualitative analysis of the implications of such heuristics for enhancing or hindering the implementation of adaptation.

Our quantitative analysis focused on identifying instances within the adaptation literature when different adaptation heuristics were invoked. We identified putative applications of adaptation heuristics by using a series of focused key word searches with the Google Scholar™ internet search

engine. Google Scholar enables searches for exact phrases within entire documents (as opposed to just titles, abstracts, or keywords) and captures a broader range of literature compared to other conventional databases such as Thomson Reuters Web of Science™. In addition, Google Scholar allows 'wild card' searches that enable multiple variants of search terms to be captured with a single search. Using Google Scholar, we searched for documents (excluding citations and patents) published over the past 10 years (2003–2012). Search terms were comprised of three components. The first two were identical across each search and consisted of the phrase climate change and the word adaptation. These components were designed to aid in focusing the search on documents with some association with climate adaptation. The third search term component varied to reflect both different heuristics as well as different language by which a given heuristic could be expressed (see Appendix Tables 3, 4, 5, 6, 7, 8, 9 and 10). Specific words used in the third component were developed by identifying language within specific documents known to the authors that was considered illustrative of a particular heuristic. That language was then used as the foundation for a brainstorming exercise to develop a list of alternative search terms designed to capture similar language and context. For each of the eight heuristics, the goal was to identify a minimum of 100 documents containing text that was potentially consistent with the various heuristics. Documents that were retained included peer-reviewed journal articles and masters and doctoral theses as well as grey literature comprised of conference papers, books and book chapters, institutional and project reports, as well as policy briefs. Documents that were presentations, abstracts for presentations, products of university course work, or for which the origins of the document could not be identified were excluded. In addition, searches that resulted in multiple versions of the same document were reconciled to avoid duplication. Most documents were available (usually in portable document format) directly through the internet or through the authors' institutional journal licenses. For journal articles for which an institutional license was not available, an attempt was made to acquire the article through the authors' institutional inter-library loan (ILL) system. Documents that could not be sourced through ILL without charge were excluded. For books and book chapters, text was often identified using Google Books™, which was used to search within books for the relevant text and accompanying page number(s).

For those documents that were identified as potentially containing heuristic devices, the specific passage of text within the document containing the specific search term was excised from the document and entered into a database. The language was then reviewed to a) validate that it was in fact consistent with the specific heuristic and b) if so, to evaluate whether that language endorsed the heuristic, was critical of the heuristic, or was neutral. Documents were classified as endorsing or critiquing a heuristic based upon a priori characteristics (Table 1). Documents were classified as being neutral for three reasons: a) spurious searches whereby the identified document didn't contain the search terms (e.g., the search phrase was split across two different sentences); b) the identified text was not germane in that it didn't address climate adaptation specifically; or c) the identified language did not make a clear statement endorsing or critiquing a particular heuristic (e.g., definitions of different concepts within adaptation). All documents and corresponding text from all search term variants for a given heuristic were compiled. This data set was used as the basis for quantitative analysis of heuristics within the adaptation literature. The quantitative analysis provides evidence of the use of heuristics in the adaptation literature as well as the relative frequency with which those heuristics are critiqued rather than endorsed. However, such quantification doesn't necessarily provide insights regarding the implications of the use of heuristics. Hence, the qualitative analysis focused on a deeper exploration of this issue. We used a subset of publications that were identified in the quantitative analysis as well as other examples to further evidence how such heuristics are applied in the adaptation literature. We then juxtapose those examples against literature that is more critical of the underlying assumptions such heuristics represent and discuss the potential consequences of relying upon heuristics that are contested.

Table 1 Adaptation heuristics explored in the current study as well as the characteristics used for classifying content from the adaptation literature as endorsing or critiquing a given heuristic

Heuristic	Endorse	Critique
Adaptation is Novel	• Adaptation is a policy or research challenge with which individuals, organizations and/or institutions have little experience	• Adaptation is an inherent characteristic of human behavior • Individuals and organizations have an extensive history of adjusting to variability and changes in weather and climate
Adaptation is Local	• Adaptation needs, planning, and implementation are dictated by processes at the local level • National and international organizations and institutions are not, or should not, be directly engaged in adaptation	• Adaptation requires collaboration among multiple actors at different scales • Local adaptation influences and/or is influenced by adaptation actions at other scales
No Regrets Adaptation	• No regrets and/or win win adaptation options are a desirable starting point for adaptation planning and implementation • No regrets options can be identified that facilitate the implementation of robust adaptation options	• Few adaptation options will be perceived as no regrets by all stakeholders • Adaptation actions should be evaluated based upon their efficacy with respect to achieving adaptation objectives • There are limits to the effectiveness of no regrets options, particularly for high magnitudes of climate change
Adaptation is Urgent	• Adaptation should be a priority consideration for individuals, organizations, and institutions • Adaptation planning and implementation should proceed rapidly	• Rapid implementation of adaptation may increases the risk of maladaptation • There may be value in delaying adaptation (i.e., real options)
Participation in Adaptation	• Stakeholders are willing to participate in adaptation planning and implementation • Stakeholder participation results in better adaptation outcomes	• Not all stakeholders are willing to participate in adaptation planning and implementation • Participation by stakeholders in decision-making doesn't necessarily result in better adaptation outcomes
Predict and respond	• Investments in science and assessment will reduce uncertainty about the future • Knowledge about future conditions and trends will enable decision-making regarding adaptation policies and measures	• Future conditions are associated with some degree of irreducible uncertainty • Adaptation planning and implementation can be pursued despite uncertainty about the future
Reactive Adaptation	• Reactive and/or autonomous adaptation is less efficient and more costly than planned adaptation • Planned adaptation should be implemented preferentially to reactive adaptation	• Reactive adaptation is important for reducing future vulnerability, particularly under conditions of high uncertainty • Reactive adaptation can be efficient and cost-effective • Reactive and anticipatory adaptation are both important for a robust adaptation response
Residual Risk	• The utility of adaptation lies in its ability to address the residual risk from climate change after accounting for greenhouse gas mitigation efforts	• Adaptation efforts have societal and/or ecological benefits independent of mitigation efforts

3 Results

3.1 Adaptation is novel

The literature frequently refers to adaptation as being a novel challenge. For example, adaptation has been described as a "new and developing discipline (McCarthy 2012, p. 31), "a relatively new research domain" (Leith 2011, p. 101), "a rather new phenomenon" (Simonsson et al. 2011, p. 325) or "a new issue" (DCC 2010, p. 6). Of the 152 documents initially identified as containing language consistent with this heuristic, 126 (83 %) were found to endorse its use and just 2 (1 %) were critical (Fig. 1). Adoption of this heuristic suggests that new institutions, policies and measures, and research are all needed to enable adaptation. However, while evidence suggests many actors may be unfamiliar with adaptation conceptually (e.g., Smith et al. 2008), in practice, climate risk management is, and always has been, a key concern for climate-sensitive enterprises (Adger et al. 2009b). Sheffer (2010, p. 12) states "there is a false assumption that adaptation planning is a 'new' idea that is yet to establish credibility or consensus in key practices," and Lambrou and Paina (2006, p. 8) argue that adaptation doesn't need to "start from scratch", but instead builds upon past experience. The introduction of the adaptation lexicon into decision-making processes does not necessarily alter actors' management objectives or options. As a case-in-point, the options available for adapting coastal systems to the effects of climate change and sea-level rise (e.g., hard and soft protection measures, retreat options, accommodation, habitat protection; Klein et al. 2001; U.S. EPA 2009) have long been in use by coastal managers. Neither the hazards nor the management options are new (Dovers 2009), and much of our knowledge regarding adaptation has evolved from understanding how institutions have responded to climate variability and extreme events in the past.

The emphasis on the novelty of adaptation unnecessarily encourages its separation from other risk management efforts rather than mainstreaming adaptation into existing policies and measures (Reisinger et al. 2011) and, in effect, places the cart before the horse (Schipper 2007). New policy issues face a regulatory commons problem (Burkett 2011), where confusion easily abounds as to who should deal with the issue. Some have also cautioned that the emphasis on adaptation is leading toward a new and separate epistemic community (Dovers and Hezri 2010), which has the potential to dismiss the lessons already learned from different management policy fields (Dovers 2009). It can also undermine stakeholder demand by posing adaptation as an additional management burden that competes with other priorities on the policy agenda (Smith et al. 2008; Measham et al. 2011). The novelty heuristic has the potential to pull attention away from the fundamental challenges of adaptation, which are associated with how to reform decision-making processes to better manage uncertainty over long time-scales and rapid rates of change, who has responsibility for implementing those reforms and the equitability with which transaction costs are distributed (Grasso 2010; Hulme et al. 2011; Petherick 2012). In the narrow context of climate change, such concerns may be new for policymakers (Li and Dovers 2011). Yet, given the dominant role that political will, leadership and social capital appear to play in advancing adaptation objectives (Adger 2003; Pelling and High 2005; Berkes 2009; Wolf et al. 2010; Ford et al. 2011), adaptation appears to largely entail reconciling competing values regarding current and future risk. In the broader context of public policy, however, this challenge is hardly a novel one.

3.2 Adaptation is local

A strong emphasis on the context-specificity of adaptation has engrained the perception that adaptation is a local process. Our search initially identified 129 documents containing language consistent with this heuristic of which 76 (59 %) endorsed its use while 10 (8 %) were critical (Fig. 1). Various studies in the literature, for example, argue that "most adaptation is local" (Tol

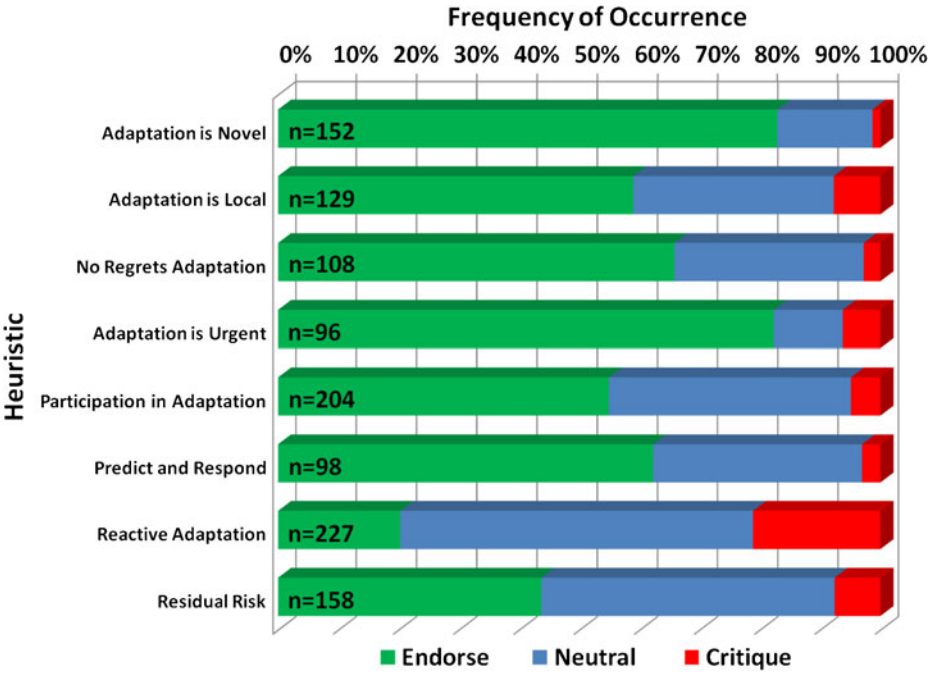

Fig. 1 Frequency with which language associated with different adaptation heuristics appeared in the Google Scholar™ internet search engine (see Appendix Tables 3, 4, 5, 6, 7, 8, 9 and 10 for additional details on search criteria). Stacked bars associated with each heuristic represent the percentage of identified documents classified (based upon characteristics in Table 1) as endorsing, critiquing or neutral with respect to that heuristic

2005, p. 577), "almost all adaptation is local" (Satterthwaite et al. 2007, p.74), and "adaptation is necessarily local" (Corfee-Morlot et al. 2011, p. 170). The proliferation of this heuristic has contributed to an increasing focus on adaptation planning and responses at the local scale (Li and Dovers 2011). In terms of public policy, the emphasis on local adaptation has often translated into local actors (public and private) having the lead responsibility for adaptation. For example, the Australian Government's perspective on adaptation is that "State, Territory and Local Governments . . . deliver more services and manage more assets than the Commonwealth Government. They will therefore have a bigger role in direct adaptation action" (DCC 2010, p. 9).

While practical implementation of adaptation may be undertaken at the local level (Grasso 2010), the evidence that the local scale is best placed to govern adaptation is less apparent. Rather, reliance upon local actors to drive adaptation appears to manifest when higher levels of government are incapable or unwilling to participate in facilitating adaptation (Measham and Preston 2012). Hence, Burton (2008, p. 1) argues that "the 'adaptation is local' mantra is no longer valid." Instead, Raymondi et al. (2012, p. 16) note that local adaptation "can be supported, coordinated, or mediated through a network of international funding, national initiatives, and regional collaboration between NGOs and communities." Adaptation by local actors is often constrained by the structure and interactions of governance systems and their capacity to support adaptation at lower levels of social, economic and political organization (Lindseth 2005; Urwin and Jordan 2008; Keskitalo and Kulyasova 2009; Keskitalo 2010). Lemos and Tompkins (2008, p. 60) therefore argue that "while all

adaptation is local, adaptive capacity is not" (see also Huntjens et al. 2010; Sprague 2012). For example, case studies from Australia document how adaptation at the scale of Local Government is constrained by acts of both omission and commission by State and Federal Governments (Smith et al. 2008; Preston and Kay 2010; Measham et al. 2011). A more robust way forward could be to pursue a process of multi-scale policy harmonization in which policies and measures at different scales are integrated to enhance the realization of adaptation objectives (Preston 2009). However, to date, such an approach remains largely theoretical. Nevertheless, a more nuanced understanding of adaptation as a multi-scaled, multi-actor process may assist in enabling researchers and practitioners to better identify scale-specific opportunities and constraints (Gero et al. 2012).

3.3 'No Regrets' adaptation

The potential costs (economic, social and environmental) associated with implementing adaptation policies and measures represent one of the key constraints on adaptation action (Adger et al. 2007; Moser and Ekstrom 2010), particularly in resource limited, developing nations. When combined with uncertainty about the benefits of adaptation, such costs create significant policy risk for adaptation actors. This policy risk acts as a constraint on adaptation, which may partly explain the relatively slow progress on adaptation implementation to date (Adger et al. 2007; Berrang-Ford et al. 2011; Ford et al. 2011; Preston et al. 2011a; Lesnikowski, et al. 2013). One widely advocated means of circumventing such constraints is by adopting a no regrets approach. Hay and Mimura (2006, p. 29), for example, state that "adaptation should pursue 'no regrets' measures and 'win–win' options." Our search identified 108 documents with language indicative of this heuristic (including similar language of 'low regrets' and 'win win' options), of which 71 (66 %) endorsed this perspective and 3 (3 %) were more critical (Fig. 1). However, varying meanings of 'no regrets' appear in the literature. For example, Burton et al. (2001, p. 890) describe 'no regrets' actions as those that "not only address current hazards but may be additionally beneficial for other reasons" (i.e., actions that yield co-benefits). Perhaps a more common understanding is that such actions yield "net social benefits under all future scenarios of climate change" (i.e., actions that are robust to climate uncertainty; Heltberg et al. 2009, p. 89; see also Campbell-Lendrum et al. 2007; Carter 2007; IPCC 2007, 2012; Hallegatte 2009). The observation that different researchers and practitioners frame the concept of regret differently and are vague regarding whose regret is being considered suggest some conceptual weaknesses of the no regrets heuristic.

A more profound and practical challenge associated with 'no regrets' approaches is their limits with respect to delivering successful adaptation outcomes. If one accepts that adaptation is, in fact, urgent (Section 3.4), 'no regrets' measures appear incommensurate with the scale of required adaptation. Meanwhile, it is difficult to conceive of options that are truly 'no regrets' (Rietbergen-McCracken et al. 2007; Sadauskis 2011; Susanne C. Moser, personal communication, May 31 2012), because they imply any opportunity costs or externalities are acceptable (or offset via co-benefits) and assume a high degree of stakeholder consensus regarding the appropriateness of the option. Patt et al. (2005) argue that expectations of potential future reductions in vulnerability for adaptation are not a sufficient criterion for labeling adaptation options as no regrets. Rather, "they should be evaluated on their more certain payoffs" (p. 422). Furthermore, due to their inherently conservative nature, 'no regrets' measures are likely to rapidly encounter adaptation limits and must therefore be followed promptly by more ambitious measures. The IPCC (2012, p. 16) SREX report, for example, identified 'low regrets' measures as "starting points for addressing projected trends in exposure, vulnerability, and climate extremes". Yet, encouraging practitioners to take the first steps without explicitly identifying follow-on actions enables single action bias where the demand for adaptation erodes after one

measure is implemented (Weber 2010). While adaptation practitioners should be encouraged to undertake no regrets measures, the reality is that successful adaptation, particularly in the absence of robust mitigation efforts, may often necessitate accepting significant policy risk in order to maintain management objectives or enable system transformations (Kates et al. 2012).

3.4 Adaptation is urgent

The rapid escalation of adaptation in both research and practice reflects an undercurrent of urgency (Corfee-Morlot et al. 2011). We identified 96 documents containing language regarding urgency, of which 79 (82 %) endorsed this heuristic, while 6 (6 %) took a more cautious stance (Fig. 1). Of the former, adaptation has been described as an "urgent need" (Ziervogel et al. 2006, p. 294; Jerneck and Olsson 2008, p. 171) and an "urgent challenge" (NISTPASS 2011, p. 11). Meanwhile, the literature on the economics of adaptation suggests that hundreds of billions of dollars will be needed per year in the near future to address adaptation costs (World Bank 2006; UNFCCC 2007a; UNDP 2007; Parry et al. 2009). Certainly, it is hard to argue against the notion of planning in the present to manage the risks of the future (Tol et al. 2008). However, if one recognizes adaptation as a process (Moser and Ekstrom 2010; Preston et al. 2011a; Park et al. 2012), a more nuanced understanding is needed of what elements of adaptation are urgent and for whom. For example, much of the rhetoric regarding the urgency of adaptation is raised in the context of vulnerable populations, particularly in least developed nations. Hence, finance mechanisms for adaptation have become a critical element of international negotiations under the UNFCCC. Yet the urgency of adaptation for vulnerable nations in the developing world is largely a function of development deficits, rather than needs arising from climate change alone. Meanwhile, Buys et al. (2012) note that many stakeholders simply don't perceive climate change to be an urgent risk.

A critical concern regarding the emphasis on urgency is that given high uncertainty, limited attribution (Hartzell-Nichols 2011; Hulme et al. 2011) and poor consensus among values (O'Brien and Wolf 2010), rushed, short-term and crises-based decision-making can lead to maladaptation (Barnett and O'Neill 2010; Tompkins et al. 2010; Scott and Baehler 2010; Thomsen et al. 2012). Evidence suggests such rushed policy responses to climate change are already occurring (Moench 2009; Barnett and O'Neill 2010). Even in the least developed nations, where vulnerability is most acute, questions have been raised regarding the robustness and appropriateness of National Adaptation Programs for Action (NAPAs), which guide the most urgent in-country adaptation priorities (MFAD and GEF 2009; Preston et al. 2011a). Given such challenges, Streilein (2008) argues for the need to first better understand the motivations and concerns of actors to enable the design of effective interventions. The tools and frameworks to enable actors to distinguish between adaptive and maladaptive responses are in their infancy (Hedger et al. 2008; GIZ 2011a, b; Lamhauge et al. 2012)—a fact which only underscores the pitfalls of forcing the issue. While the assessment of and strategic planning for the potential implications of climate change is urgent, the timing of implementation is context-dependent. Delaying certain decisions may create, or at least preserve, future opportunities (Barnett and O'Neill 2010; Tompkins et al. 2010).

3.5 Participation in adaptation

Adaptation research and practice focuses extensively on the analysis of adaptation under fairly optimal conditions of implementation. Such optimism is evident within environmental management at large, with Andersson and Ostrom (2008) noting prevailing assumptions regarding the willingness of actors to govern common pool resources effectively and equitably. A similar presumption is discernible in adaptation where actors are assumed to be ready, willing and able to adapt. This willingness to participate is particularly important given the belief that such participation "…is

needed in all the processes that increase resilience of, and decrease reliance on, vulnerable sectors…" (UNFCCC 2007b, p. 8). Often this willingness is implicit within the rhetoric of adaptation being "a shared responsibility" (Hammer 2004; DCC 2010; Yusoff 2011; Thompson et al. 2012) that necessitates participation by any and every stakeholder with a stake in the process or its outcomes. Literature invoking the concept of participation was readily identified, with 204 documents containing language initially consistent with a heuristic of participation (Fig. 1). However, a significant fraction (40 %) of these documents was spurious in that documents were not specific to climate adaptation. This was likely a function of participation being a key theme in environmental science and management generally. Nevertheless, 112 (55 %) and 10 (5 %) of documents initially retrieved were found to either endorse or critique, respectively, conventional wisdom regarding the role of participation. Ebi (2011, p. 124) notes that "stakeholders should be engaged in all steps" of adaptive management efforts regarding public health and climate change. Similarly, Wilhelmi and Hayden (2010, p. 5), challenge "the researcher and public health practitioner to engage the public at multiple levels." Often, different elements of the governance network are seen as predisposed to participation in such policy-making processes (Arnstein 1969; Fisher 2003; Forester 1999). This is evident, for example, within Australian local governments' adaptation planning where the concept of shared responsibility is used to distribute responsibilities among different actors (Burton and Mustelin 2013).

In practice, however, many potential adaptation actors will simply choose not to participate, either because they have no interest (Burton 2009b), because they are preoccupied with more significant priorities (Tol et al. 2008; Handmer and Dovers 2009; Moench 2009; Smith et al. 2008; Measham et al. 2011), or because adaptation is simply not relevant to their management objectives. While the opportunities for participation should be enhanced for those members of the public who want to engage in decision-making processes, it cannot be assumed that more participation is always better or results in better policy outcomes (Richardson 1983; Burton 2009b; Burton and Mustelin 2013). Several authors have noted that stakeholder engagement efforts are often poorly structured, resulting in ad hoc or biased participation (Weinestedt 2009; Brown et al. 2011; Rinner et al. 2011; Cromp et al. 2012; Brick et al. 2013). For example, Catchpole (2008) and McKinney et al. (2010) cite instances of disagreement regarding which stakeholders should or should not be included in participatory processes. Given the lack of empirical evidence to track the benefits and outcomes of participation, confusion as to which actors and stakeholders should be involved and how (Burton 2009b), and potential fear of policymakers to involve the public (Wesselink et al. 2008), placing unvalidated faith in the utility of broad participation in adaptation appears premature. Even in cases where willingness is present, adaptation constraints impede action (Berkhout et al. 2006; Moser and Ekstrom 2010; Measham et al. 2011), suggesting potential disconnects between willingness to adapt and actual adaptation (Berrang-Ford et al. 2011; Preston et al. 2011b). By exploring the nuances of how climate adaptation may or may not interact with actors' objectives and business models, adaptation policy can be guided by a more refined understanding of which actors are critical to particular adaptation strategies and which may act as potential barriers.

3.6 Predict and respond

As adaptation has traditionally been framed as adjustments to anticipated changes in future climate conditions (IPCC 2001), adaptation research places a strong emphasis on developing insights regarding future climatic and socioeconomic states and trends. These insights can largely be classified into three categories: a) projections of future climate conditions; b) projections of future societal and/or ecological vulnerability; and c) projections of the costs/benefits of different adaptation options. Our exploration of the adaptation literature

retrieved 98 documents which contained language consistent with a predict and respond approach to adaptation (Fig. 1). Of these, 61 (62 %) endorsed this approach, while 3 (3 %) were critical. The vast majority of documents adopting a predict and respond stance referred to the need for improvements in climate projections/predictions generally, and, in particular, the use of downscaling methods to improve regional-scale analysis. Prober et al. (2012, p. 244) notes that the management of ecosystem impacts is "constrained by high uncertainty, and a better understanding of non-linear relationships and thresholds, coupled with improved climate prediction, is needed." Biringer et al. (2005, p. 157) states "the first step in examining climate change effects on biodiversity requires downscaling of GCM [general circulation model] data." The pursuit of predictions conforms to the emphasis on 'evidence-based' decision-making that adopts (implicitly or explicitly) a 'knowledge deficit' or 'rational actor' model of decision-making (Wynne 1991, 2006; Schön and Rein 1994; Stokes 1997; Hansen et al. 2003; Godin 2006; Trench 2008; Heazle 2010). The assumed policy-relevance of improved prediction has also been expressed in the science policy and adaptation practitioner arenas. For example, the Australian Department of Climate Change (DCC 2009, p. 6) justifies its investments in climate science by arguing that it is "the essential system knowledge without which adaptation strategies and mitigation strategies cannot readily be built". Meanwhile, Hickox and Nichols (2003), argue that "reducing uncertainty in projections of future climates is critical to progress [on adaptation]."

Reliance upon the predict and respond heuristic to guide adaptation practice effectively paints practitioners into a corner, because uncertainty cannot be eliminated. Several authors have been critical of the assumption that more accurate/precise information about future climate is needed to adapt to climate change (Adger et al. 2009a; Dessai et al. 2009), as well as the utility of vulnerability assessment methods and metrics for informing adaptation decision-making (Barnett et al. 2008; Klein 2009; Preston et al. 2009; Hinkel 2011; Preston et al. 2011b). For example, Barnett and O'Neill (2010) argue that recent large-scale infrastructure solutions for managing water resource insecurity in Melbourne, Australia, which were justified in part on long-term climate projections of declining rainfall, are maladaptive (see also Productivity Commission 2011). Todd et al. (2010) argue that reducing uncertainty about future hydroclimatological conditions is unlikely due to the long-term stability in estimates of global climate sensitivity and the tendency for the incorporation of additional processes and/or downscaling methods to introduce additional uncertainty into climate predictions. Similarly, Graeff et al. (2012, p. 7) assert that increasing climate model resolution could be counterproductive as "model performance might get worse at smaller scales." This suggests the need for researchers and practitioners to be more circumspect in assessing the utility of prediction for adaptation. Rather than literal, direct applications of predictions in decision-making, such predictions can be used for their diagnostic and pedagogical value with respect to elucidating system sensitivities and thresholds (Jones 2001; Dessai et al. 2004), facilitating deliberation (Preston et al. 2009; Yuen et al. 2012) and contributing to the weight-of-evidence that may inform possible adaptation responses. This framing, however, significantly alters the mental model of how such information should be used to facilitate adaptation from predict and respond to predict and learn.

3.7 Reactive adaptation

The adaptation literature has long made a distinction between reactive adaptation and planned adaptation. These terms are often used synonymously with those of autonomous and anticipatory adaptation, respectively, although at times distinctions are made (e.g., Walker et al. 2010). One common heuristic device which appears in the literature is to frame

reactive adaptation as being less efficient, more costly, and more prone to failure than planned adaptation. Our search of the adaptation literature for language consistent with this perspective retrieved 227 documents (Fig. 1). However, the majority (59 %) of these simply defined reactive and planned adaptation as two general approaches with little discussion of their relative merits. The remaining 41 % were evenly split with half endorsing reactive adaptation as inadequate or suboptimal and half critiquing this assumption and/or identifying conditions under which reactive adaptation is particularly important. The argument against reactive adaptation is exemplified by Church et al. (2010, p. 414) who state "planned adaptation is more cost effective and less disruptive than forced adaptation in response to the impacts of extreme events". Similarly, Price and Neville (2003, p. 80) consider it "very unlikely that adaptation after the fact could prove successful" and Repetto (2008, p. 2) asserts that reactive adaptation "will be especially costly." Collectively, these perspectives reflect an underlying objective of seeking the least-cost path to adaptation, under relatively optimal conditions of foresight and efficient institutions.

Both adaptation research and practice have demonstrated, however, that such optimal conditions are unlikely to materialize. Some researchers are now shifting away from assuming optimal conditions toward 'second best' climate change policy responses (Bennear and Stavins 2007; Richels et al. 2009; Bauer et al. 2011). This perhaps explains why documents offering a critical perspective on this heuristic were just as numerous as those endorsing it. One common critique is that limits to human foresight pose significant constraints on the ability of actors to plan efficiently. Burton et al. (2006, p. 10), for example, state, "uncertainties in the extent, timing, and distribution of impacts make it harder to determine the appropriate level of investment." Meanwhile, Hall and Weiss (2012, p. 324) argue that reactive adaptation may be a better option than "proactive projects with uncertain value." Similarly, Kolev (2012, p. 47) notes that as an immediate or near-term response, reactive adaptation "is less directly affected by the choice of discount rates." Despite its inefficiencies, there is ample evidence of public institutions acting in a mode of reactive policy-making (Easterling et al. 2004; Burton et al. 2006), and others have argued that adaptation, too, is unlikely to proceed purely as responses to anticipated climate change (Adger et al. 2007; Ford et al. 2011). Hence, reactive adaptation may, in itself, be adaptive in the context of complex democratic governance systems where values are continually being traded-off against one another. Finally, as suggested by Grasso (2010), the traditional dichotomy of reactive and anticipatory adaptation may be a false one, with adaptation processes rather being a more dynamic interaction among experience and foresight, constraints and opportunities and reactive and anticipatory framings. While this reconceptualizing of adaptation may reduce the marginalization of reactive adaptation, it also suggests that appropriate conditions need to be created to allow reactive adaptation to occur in effective ways.

3.8 Residual risk

Adaptation is often not framed as a stand-alone strategy for risk management, but rather as a means of addressing the residual consequences that cannot be avoided through greenhouse gas mitigation efforts (Jones 2004). Of the 158 documents we identified with language consistent with this heuristic, 69 (44 %) were judged to endorse its use, while 12 (8 %) were critical (Fig. 1). That left a significant fraction that was not directly relevant to climate adaptation. Moser et al. (2009c; p. 62), illustrate this heuristic in citing the need to adapt "to the impacts that cannot be avoided." Hence, adaptation is complementary to mitigation and thus its utility is assumed to be directly linked to mitigation efforts. In this context,

MacLellan (2007, p. 46) argues that "adaptation and mitigation are complementary responses to climate change, and we are entreated to consider them together." Similarly, Kpadonou et al. (2012, p. 185) state "adaptation alone cannot eliminate all the negative impacts and mitigation is crucial to limit changes in the climate system."

Other authors, however, note that while adaptation and mitigation are considered complementary within some disciplines, "*the economic literature offers almost opposite views*" (Buob and Stephan; 2008, p. 5), because "*they inevitably involve tradeoffs in a world of limited resources"* (Lin 2012, p. 28). If actors are forced into making choices between investments in mitigation and adaptation, this alters the perception of adaptation as a treatment for residual risk after mitigation. Furthermore, according to Jones et al. (2007, p. 687), "the fact that [mitigation and adaptation] manage different aspects of climate risk may not matter to stakeholders," as decision-makers seeking to manage local risks posed by climate change are unlikely to consider future mitigation potential in their planning. In fact, in the absence of a robust international framework for mitigation, the residual risk heuristic reduces adaptation to an attempt to hit a moving climate target, with some suggesting the need to adapt to much higher magnitudes of climate change than previously considered (e.g., Fung et al. 2011; Stafford Smith et al. 2011; Thornton et al. 2011). Hence, while the scale of mitigation efforts will certainly influence adaptation needs and demand, scaling adaptation efforts to assumptions about future mitigation does not currently appear to be a robust strategy for risk management.

4 Discussion

Many of the core principles, methods, and tools relevant to climate adaptation are based upon rules of thumb that have become established through the natural process of disciplinary development. Such heuristics have an important role to play in providing the building blocks for advances in adaptation research and for guiding adaptation actors in the challenging effort of decision-making under uncertainty. In fact, as indicated by Ravetz (1972), the establishment of a set of common assumptions may in fact be a critical process in the development of rigorous research as well as robust practice. When decision problems are complex and/or when knowledge is limited or ambiguous, heuristic reasoning may be employed "…to reduce difficult mental tasks to simpler ones" (Slovic et al. 1982, p. 464), or to translate theories regarding the rules that govern complex system into conventional wisdom. Adaptation cannot advance if conceptual understanding of adaptation processes must be rediscovered and renegotiated at the onset of every research endeavor or planning process.

As evidenced in our exploration of the adaptation literature, heuristic devices can be readily identified that serve as the a priori points of departure for investigations of adaptation processes or for adaptation planning and implementation. In this capacity, however, it is imperative that heuristics are relevant and robust to the contexts to which they are applied. Otherwise, they can act to constrain rather than facilitate adaptation. Arguing, for example, that adaptation is local can shift responsibility for adaptation to local actors who are often not well-resourced to undertake adaptation. This problem of adaptive capacity at the local level is one reason why mechanisms have been established (e.g., Least Developed Country Fund) to provide assistance to national governments of least developed countries for adaptation efforts. The novelty heuristic contributes to the perception of knowledge deficit, which can become an excuse to push decisions further into the future. Meanwhile, arguing that adaptation implementation is contingent upon reduced uncertainty in climate prediction is

inconsistent with the evidence that adaptation is already occurring (Adger et al. 2007). Hence, there appears to be room for improvement with respect to the various adaptation heuristics currently in use. To this end, it is useful to explore alternative framings for heuristics that are more robust given current criticisms and limitations (Table 2).

Realizing such improvement, however, requires understanding the manner in which heuristics enter the adaptation discourse. The origins of heuristics can be found within theories of cognitive reasoning—modes of argumentation and evidence that people use to make sense of their world (Kahneman et al. 1982; Slovic et al. 1982; Newstead et al. 2002; Evans 2003, 2006; Osman 2004; Hadjichristidis et al. 2007). Information processing occurs through associative and affective reasoning or through analytic reasoning (Weber 2010; Osman 2004). The affective and associative reasoning focuses on personal experience, is innate and relies on quick associations (Weber 2010; Evans 2003). Analytic reasoning, in contrast, is generally slow and methodical, controlled rather than automatic or instinctive, and susceptible to the introduction of new evidence and information (Evans and Over 1996; Stanovich 1999; Weber 2010). As an academic enterprise, one would assume that adaptation science is largely entrenched within an analytic reasoning framework, yet adaptation researchers clearly make frequent use of heuristics. Meanwhile, because the dynamics of decision-making in policy environments may be short-term and opportunistic rather than deliberate (Handmer and Dovers 2009), adaptation practice may rely more heavily upon heuristic reasoning. In addition, those involved in adaptation practice are more likely to rely upon experiential knowledge and alternative ways of knowing than the direct transfer of scientific knowledge into practice (Bäckstrand 2004; Goldstein 2009; Oppermann 2011). Yet, adaptation practice is a key venue in which heuristics can be put to the test and critically evaluated for their utility.

On a more practical level, adaptation heuristics are socialized among researchers and practitioners through individual and social learning. This includes constructionist experiential learning (Hagmann and Chuma 2002; Blackmore 2007; Yuen et al. 2012), whereby heuristics are developed based upon an individual's framing of experience and its assigned meanings. The 'availability heuristic', for example, represents a phenomenon in which individuals' perceptions of the future risk of an event are shaped by their experience and the ease with which a comparable event can be recalled (Slovic et al. 1982; Godwa 1999; Moser 2009b; Leiserowitz 2005; Corfee-Morlot et al. 2011; Weber 2010). Similarly, Smith et al. (2008) and Measham et al. (2011) report that local government staff in Sydney, Australia often equated energy conservation and greenhouse gas reduction measures with adaptation due to an extensive prior experience with mitigation. However, heuristics are not learned simply through experience. In many instances, they are taught and reinforced through didactic learning (Lorenzoni et al. 2000; Irandoust 2009; Burandt and Barth 2010). Formal scientific assessment processes such as those conducted under the auspices of the United Nations Intergovernmental Panel on Climate Change are frequently framed as vehicles by which policy-relevant scientific knowledge is delivered into the hands of decision-makers. Similarly, the current study identified a broad range of heuristics that appeared not just in the peer-reviewed literature, but also in guidance for practitioners regarding the planning and implementation of adaptation from the World Bank (Agrawal et al. 2008; Kuriakose et al. 2009), the United Nations Development Programme (Lim et al. 2005), as well as national government agencies (UK Stationary Office 2010; Brown et al. 2011).

The current study evidences the continual critique of conventional wisdom by researchers and/or practitioners. For each heuristic explored through our literature search, it was possible to identify documents in which the heuristic was viewed through a critical lens. Such

Table 2 Proposed alternative framings of adaptation heuristics discussed in the current study. Heuristics can be transformed from their current dominant framing to an alternative framing that is potentially more robust to adaptation research and practice

Heuristic	Current	Alternative
Adaptation is Novel	Climate change poses novel problems to actors due to the lack of previous experience	Climate change adaptation raises new concerns regarding familiar problems while simultaneously facilitating deeper reflections as to its novelty
Adaptation is Local	Adaptation is largely a local concern and solutions are most effective on local scale	Climate change vulnerability transcends multiple geopolitical scales making reliance on only local scale responses potentially ineffective
No Regrets Adaptation	Actors should focus on 'no regrets' and win-win adaptation to minimize potential constraints	Truly 'no regrets' actions may be difficult to identify and are likely to encounter limits with respect to their capacity to ensure the maintenance of critical values
Adaptation is Urgent	Adaptation actions need to be implemented urgently to manage climate risk and may require transformation	Critical appraisal of appropriate adaptation actions is needed over the near-term to establish flexibility in the timing of implementation of options
Participation in Adaptation	Actors are willing to adapt and take responsibility for adaptation and such actions will be supported and implemented by civil society	Participation in adaptation will be unequal and characterized by debate among actors regarding responsibilities
Predict and respond	More precise estimates of future climate change, vulnerability, and risk are critical for informing decision-making on the selection and implementation of adaptation measures	Exploration of alternative biophysical and socioeconomic futures and their implications for systems of value can be valuable for facilitating learning regarding adaptation, but uncritical application of such knowledge in decision-making can lead to maladaptation
Reactive Adaptation	Reactive adaptation is inefficient and thus subordinate to more anticipatory adaptation actions	All adaptation is reactive and reactive approaches may be rational and effective given the range of sociopolitical constraints experienced by actors
Residual Risk	Adaptation addresses the risks associated with climate change that cannot be avoided via greenhouse gas mitigation	Planning and implementation of adaptation should be pursued independent of anticipated progress on greenhouse gas mitigation

reflexive application of analytical reasoning to heuristics arises when evidence emerges that accepted conventional wisdom fails to explain observed behavior or outcomes. Triggering analytic reasoning is dependent on the interaction between science and policy as actors in both spheres contribute to the creation and subsequent use of heuristics (Dilling and Lemos 2011). For example, the persistent inability for climate modelers to constrain future uncertainties in climate prediction may cause practitioners to reevaluate whether investing in such predictive tools is in fact the most robust approach to informing adaptation decision-making. Subsequently, modelers may begin to question their own assumptions and seek more innovative ways of extracting utility from model results. Alternatively, research regarding methods used by public institutions to engage stakeholders in adaptation planning and

implementation may reveal insights that lead to reforms in how such engagements are structured. Capturing the learning from adaptation practice is therefore a critical pathway for the development of more robust heuristics (e.g., Hedger et al. 2008; GIZ 2011b; Lamhauge et al. 2012). However, adaptation research should undergo similar scrutiny given its role in defining what is accepted as conventional wisdom.

These interactions between research and decision-making as well as between heuristic and analytical reasoning suggest the need for greater integration of adaptation science and practice, rather than treating each as a separate enterprise (Moser and Ekstrom 2010; Preston et al. 2013). Strong precedents and arguments in favor of such collaborative approaches to learning and decision-making can be found in the policy sciences and adaptive governance literature (Clark 2002; Brunner et al. 2005; Folke et al. 2005; Nelson et al. 2007, 2008; Lynch et al. 2008; Brunner and Lynch 2010). In this collaborative context, it is important to acknowledge the underlying heuristics that are being used to guide adaptation processes and continually question their legitimacy. This form of reflexive or double loop learning is necessary to ensure both researchers and practitioners have appropriately framed their adaptation problems and are relying upon robust heuristics to guide their decision-making (Flood and Romm 1996; Groot and Maarleveld 2000; Leeuwis and Pyburn 2002; Yuen et al. 2012). Otherwise, heuristics can become a constraint rather than an enabling tool, which can lead to inefficiency, inefficacy, and maladaptation (Barnett and O'Neill 2010).

5 Conclusions

This paper began with the assertion that although adaptation science has evolved relatively rapidly in recent years, significant challenges persist in the translation of that science into robust policy and practice. There is evidence that the conceptual models, tools and methods developed by the research community have either not sufficiently evolved or have not been effectively delivered to guide adaptation (Klein and Juhola 2013). While the limitations or even failures of applied adaptation science eventually become evident leading to more critical appraisal of research methods, in the meantime, that knowledge is employed by practitioners and other researchers, often with less of an analytical and reflexive lens. We find that the heuristic reasoning employed in adaptation research and practice often fails to reflect the nuances associated with the practical pursuit of adaptation. Hence, while heuristics have proven useful in framing and clarifying the characteristics of climate change adaptation, they need to be accompanied by critical reflection and evaluated for their robustness. While it is possible to identify literature critiquing the use of some common heuristics, such critiques are often in the minority. In order to adequately evaluate whether particular heuristics are useful and robust, there is an increasing need for critical mutual reflection between scientists and practitioners as to which assumptions, heuristics, and adaptation principles enable successful adaptation in practice. In this endeavor, we would do well to promote coproduction of knowledge in both theory and practice as crucial factors in increasing our own adaptive capacity to advance and further develop the relevance, practicality and effectiveness of adaptation research.

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Appendix

Search criteria used with the Google Scholar search engine to identify documents containing putative language consistent with the use of adaptation heuristics as identified and defined in the current study. Each search term was comprised of three components: component A = "climate change"; component B = "adaptation" and component C which was variable. The tables below summarize the C components for each heuristic and the number of documents identified that were included in the current study and Fig. 1. Asterisk indicates a 'wild card' search.

Table 3 Search criteria (component C) for the Adaptation is Novel heuristic (Search Date: 6/3/2013)

Search #	Search terms	Number included
A	"adaptation to climate change is new"	1
B	"adaptation to climate change is a new"	10
C	"adaptation to climate change is a * new"	20
D	"adaptation is a new"	30
E	"adaptation is a * new"	37
F	"adaptation * is new"	5
G	"adaptation * is a new"	8
H	"adaptation * are a new"	0
I	"adaptation to climate change is novel"	0
J	"adaptation to climate change is a novel"	1
K	"adaptation to climate change is a * novel"	1
L	"adaptation is novel"	0
M	"adaptation * is novel"	1
N	"adaptation is a * novel"	0
O	"adaptation is a novel"	0
P	"adaptation * is a novel"	0
Q	"adaptation * are a novel"	0
R	"adaptation * area * novel"	0
S	"adaptation to climate change is an unfamiliar"	0
T	"adaptation to climate change is a * unfamiliar"	0
U	"adaptation is an unfamiliar"	0
V	"adaptation * is an unfamiliar"	0
W	"adaptation * are an unfamiliar"	0
X	"adaptation to climate change is an unprecedented"	0
Y	"adaptation to climate change is a * unprecedented"	0
Z	"adaptation is an unprecedented"	0
AA	"adaptation * is an unprecedented"	0
AB	"adaptation * are an unprecedented"	0
AC	"adaptation to climate change is an emerging"	2
AD	"adaptation is an emerging"	13
AE	"adaptation * is an emerging"	10
AF	"adaptation to climate change is a recent"	0
AG	"adaptation to climate change is a * recent"	2
AH	"adaptation is a recent"	2

Table 3 (continued)

Search #	Search terms	Number included
AI	"adaptation is a * recent"	4
AJ	"adaptation * is a recent"	2
AK	"adaptation * is a * recent"	3
Total		**152**

Table 4 Search criteria (component C) for the Adaptation is Local heuristic (Search Date: 3/10/2013)

Search #	Search terms	Number included
A	"adaptation is local"	47
B	"adaptation is * local"	58
C	"adaptation * be local"	5
D	"adaptation is place based"	5
E	"adaptation is * place based"	4
F	"adaptation * be place based"	0
G	"adaptation is community based"	1
H	"adaptation is * community based"	2
I	"adaptation * be community based"	0
J	"adaptation occurs at the local level"	3
K	"adaptation * occurs at the local level"	0
L	"adaptation * occur at the local level"	3
M	"adaptation * implemented at the local level"	1
N	"adaptation is * implemented at the local level"	0
Total		**129**

Table 5 Search criteria (component C) for the No Regrets heuristic (Search Date: 3/14/2013)

Search #	Search terms	Number included
A	"* pursue no regrets *"	8
B	"* pursue low regrets *"	0
C	"* pursue win win *"	7
D	"* implement no regrets *"	13
E	"* implement low regrets *"	0
F	"* implement win win *"	7
G	"* investigate no regrets *"	2
H	"* investigate low regrets *"	0
I	"* investigate win win *"	0
J	"* consider no regrets *"	7
K	"* consider low regrets *"	0
L	"* consider win win *"	0
M	"* select no regrets *"	0
N	"* select low regrets *"	0

Table 5 (continued)

Search #	Search terms	Number included
O	"* select win win *"	2
P	"* choose no regrets *"	1
Q	"* choose low regrets *"	0
R	"* choose win win *"	1
S	"no regrets * should be"	14
T	"no regrets * must be"	1
U	"low regrets * should be"	0
V	"low regrets * must be"	0
W	"win win * should be"	16
X	"win win * must be"	6
Y	"investigate * win win"	1
Z	"* considered low regrets"	1
AA	"* considered no regrets"	8
AB	"* considered no regret"	13
Total		**108**

Table 6 Search criteria (component C) for the Adaptation is Urgent heuristic (Search Date: 3/13/2013)

Search #	Search terms	Number included
A	"adaptation is urgent"	15
B	"adaptation is an urgent"	5
C	"there is an immediate need for adaptation"	1
D	"immediate adaptation is needed"	1
E	"adaptation is needed immediately"	0
F	"adaptation will be needed immediately"	0
G	"adaptation is needed now"	5
H	"adaptation will be needed soon"	0
I	"adaptation is a priority"	30
J	"adaptation should be a priority"	4
K	"adaptation must be a priority"	2
L	"adaptation is a high priority"	3
M	"adaptation should be a high priority"	2
N	"adaptation must be a high priority"	0
O	"must prioritize adaptation"	1
P	"make adaptation a priority"	4
Q	"pressing need for adaptation"	14
R	"adaptation strategies are urgent"	0
S	"adaptation policy is urgent"	0
T	"adaptation options is urgent"	0
U	"adaptation options are urgent"	0
V	"adaptation * is urgent"	9
Total		**96**

Table 7 Search criteria (component C) for the Participation in Adaptation heuristic (Search Date: 3/27/2013)

Search #	Search terms	Number included
A	"adaptation is a shared responsibility"	2
B	"climate risk management is a shared responsibility"	1
C	"there is a shared responsibility"	10
D	"stakeholders must be engaged"	18
E	"stakeholders should be engaged"	49
F	"stakeholders should be included"	23
G	"stakeholders must be included"	13
H	"engagement of stakeholders is "	11
I	"stakeholder engagement is critical"	8
J	"stakeholder engagement is important"	12
K	"stakeholder engagement is necessary"	2
L	"stakeholder participation is critical"	4
M	"stakeholder participation is necessary"	3
N	"stakeholder participation is essential"	16
O	"stakeholder participation is important"	9
P	"participation by stakeholders is critical"	1
Q	"participation by stakeholders is necessary"	0
R	"participation by stakeholders is essential"	0
S	"participation by stakeholders is important"	0
T	"participatory approaches are critical"	0
U	"participatory approaches are necessary"	2
V	"participatory approaches are essential"	4
W	"participatory approaches are important"	3
X	"stakeholder participation is vital"	7
Y	"stakeholder engagement is vital"	3
Z	"participation by stakeholders is vital"	0
AA	"participatory approaches are vital"	3
Total		**204**

Table 8 Search criteria (component C) for the Predict and Respond heuristic (Search Date:3/20/2013)

Search #	Search terms	Number included
A	"improvements in climate * are needed"	0
B	"improvements in climate change * are needed"	0
C	"improved climate * is needed"	1
D	"improved climate * are needed"	1
E	"improved climate change * is needed"	0
F	"improved climate change * are needed"	0
G	"improvements in climate * are necessary"	0
H	"improvements in climate change * are necessary"	0
I	"improved climate * is necessary"	0
J	"improved climate * are necessary"	0

Table 8 (continued)

Search #	Search terms	Number included
K	"improved climate change * is necessary"	0
L	"improved climate change * are necessary"	0
M	"improvements in climate * are required"	0
N	"improvements in climate change * are required"	0
O	"improved climate * is required"	0
P	"improved climate * are required"	0
Q	"improved climate change * is required"	0
R	"improved climate change * are required"	0
S	"better climate * are needed"	1
T	"better climate change * are needed"	1
U	"better climate * is needed"	1
V	"better climate change * is needed"	0
W	"need better climate *"	1
X	"need improved climate *"	0
Y	"requires improved climate *"	2
Z	"requires better climate *"	0
AA	"downscaling is necessary"	24
AB	"downscaling is essential"	3
AC	"downscaling is required"	20
AD	"requires downscaling"	26
AE	"higher resolution models are *"	12
AF	"higher resolution modeling is *"	4
AG	"requires higher resolution modeling*"	1
Total		**98**

Table 9 Search criteria (component C) for the Reactive Adaptation heuristic (Search Date: 3/10/2013)

Search #	Search terms	Number included
A	"climate change" adaptation "reactive adaptation is *"	63
B	"climate change" adaptation "autonomous adaptation is *"	148
C	"climate change" adaptation "planned adaptation is more *"	6
D	"climate change" adaptation "anticipatory adaptation is more *"	4
E	"climate change" adaptation "reactive adaptation is less *"	2
F	"climate change" adaptation "autonomous adaptation is less *"	0
G	"climate change" adaptation "more * to pursue anticipatory adaptation"	0
H	"climate change" adaptation "more * to pursue planned adaptation"	0
I	"climate change" adaptation "less * to pursue reactive adaptation"	0
J	"climate change" adaptation "less * to pursue autonomous adaptation"	0
K	"climate change" adaptation "more * to implement anticipatory adaptation"	0
L	"climate change" adaptation "more * to implement planned adaptation"	0
M	"climate change" adaptation "less * to implement reactive adaptation"	0
N	"climate change" adaptation "less * to implement autonomous adaptation"	0

Table 9 (continued)

Search #	Search terms	Number included
O	"climate change" adaptation "rather than autonomous adaptation"	0
P	"climate change" adaptation "rather than planned adaptation"	2
Q	"climate change" adaptation "instead of autonomous adaptation"	0
R	"climate change" adaptation "instead of reactive adaptation"	2
Total		**227**

Table 10 Search criteria (component C) for the Residual Risk heuristic (Search Date: 3/10/2013)

Search #	Search terms	Number included
A	"climate change" adaptation "adaptation and mitigation are complementary"	17
B	"climate change" adaptation "mitigation and adaptation are complementary"	29
C	"climate change" adaptation "residual risk remaining"	7
D	"climate change" adaptation "residual risk after"	15
E	"climate change" adaptation "impacts that can't be avoided"	0
F	"climate change" adaptation "consequences that can't be avoided"	0
G	"climate change" adaptation "risks that can't be avoided"	0
H	"climate change" adaptation "impacts that cannot be avoided"	42
I	"climate change" adaptation "consequences that cannot be avoided"	5
J	"climate change" adaptation "risks that cannot be avoided"	4
K	"climate change" adaptation "impacts that could not be avoided"	3
L	"climate change" adaptation "consequences that could not be avoided "	0
M	"climate change" adaptation "risks that could not be avoided "	0
N	"climate change" adaptation "impacts that can't be prevented"	0
O	"climate change" adaptation "consequences that can't be prevented"	0
P	"climate change" adaptation "risks that can't be prevented"	0
Q	"climate change" adaptation "impacts that cannot be prevented"	4
R	"climate change" adaptation "consequences that cannot be prevented"	0
S	"climate change" adaptation "risks that cannot be prevented"	1
T	"climate change" adaptation "impacts that could not be prevented"	0
U	"climate change" adaptation "consequences that could not be prevented "	0
V	"climate change" adaptation "risks that could not be prevented "	0
W	"climate change" adaptation "impacts that can't be mitigated"	1
X	"climate change" adaptation "consequences that can't be mitigated"	0
Y	"climate change" adaptation "risks that can't be mitigated"	0
Z	"climate change" adaptation "impacts that cannot be mitigated"	9
AA	"climate change" adaptation "consequences that cannot be mitigated"	0
AB	"climate change" adaptation "risks that cannot be mitigated"	3
AC	"climate change" adaptation "impacts that could not be mitigated"	0
AD	"climate change" adaptation "consequences that could not be mitigated "	0
AE	"climate change" adaptation "risks that could not be mitigated "	0
AF	"climate change" adaptation "because of committed warming"	3
AG	"climate change" adaptation "due to committed warming"	1

Table 10 (continued)

Search #	Search terms	Number included
AH	"climate change" adaptation "in response to committed warming"	0
AI	"climate change" adaptation "due to the warming commitment"	0
AJ	"climate change" adaptation "because of the warming commitment"	1
AK	"climate change" adaptation "impacts which cannot be avoided"	9
AL	"climate change" adaptation "consequences which cannot be avoided"	1
AM	"climate change" adaptation "risks which cannot be avoided"	2
AN	"climate change" adaptation "impacts which cannot be mitigated"	1
AO	"climate change" adaptation "consequences which cannot be mitigatedd"	0
Total		**158**

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