Reg Environ Change
DOI 10.1007/s10113-014-0663-3

ORIGINAL ARTICLE

Situating adaptation: how governance challenges and perceptions of uncertainty influence adaptation in the Rocky Mountains

Carina Wyborn · Laurie Yung · Daniel Murphy · Daniel R. Williams

Received: 21 March 2014 / Accepted: 10 July 2014

Abstract Adaptation is situated within multiple, interacting social, political, and economic forces. Adaptation pathways envision adaptation as a continual pathway of change and response embedded within this broader sociopolitical context. Pathways emphasize that current decisions are both informed by past actions and shape the landscape of future options. This research examines how adaptation actors in Grand County, Colorado perceive adaptation in the context of environmental change and uncertainty. Grand County residents drew on experiences of past change to suggest they had a high capacity to respond to future change, in particular a significant outbreak of mountain pine beetle. While residents and land managers characterized adaptation as gradual and incremental, they also recognized the ways that powerful cross-scale processes related to federal land management and water diversions challenged local adaptation. Further, Grand County residents identified multiple uncertainties in addition to those associated with climate projections, suggesting that addressing uncertainty extends beyond developing strategies robust across different climate scenarios. The challenges of uncertainty and cross-scale governance require more than increased adaptive capacity; they demand that we understand how local and extra-local structures shape the adaptation envelope that enables and constrains local decisions and implementation. Within this envelope, local actors pursue particular adaptation pathways and exercise agency to influence the structures shaping their options. Drawing on empirical insights, we argue that the concepts of pathways and envelopes together provide theoretical space for understanding the dynamic interplay between structure and agency in the context of adaptation.

Keywords Adaptation · Adaptation pathways · Governance · Scale · Uncertainty · USA

Editor: James D. Ford.

C. Wyborn (✉) · L. Yung
College of Forestry and Conservation, University of Montana, Room 304, Main Hall, Missoula, MT, USA
e-mail: carina.wyborn@umontana.edu

L. Yung
e-mail: laurie.yung@umontana.edu

D. Murphy
Department of Anthropology, University of Cincinnati, Cincinnati, OH, USA
e-mail: murphdl@ucmail.uc.edu

D. R. Williams
Rocky Mountain Research Station, United States Forest Service, Washington, DC, USA
e-mail: drwilliams@fs.fed.us

Introduction

Inertia in the climate system will drive a certain level of warming even with effective and immediate mitigation (Wetherald et al. 2001), making adaptation a pressing concern. To date, the climate adaptation literature has largely been conceptual or overly focused on technologically driven adaptation led by formal institutions (Thornton and Manasfi 2010). Moreover, we argue that while research on climate adaptation has identified a number of social, political, and institutional processes shaping adaptation, this research remains largely isolated from theoretical social science understandings of how social structures constrain or enable actors to undertake adaptation. There are, however, an increasing number of empirical case

Published online: 14 August 2014

studies of the views and practices of adaptation actors in various contexts.

We contribute to this emerging body of knowledge on adaptation actors through case study research in Grand County, Colorado. We define adaptation actors as people positioned to make adaptation decisions or otherwise influence adaptation. This paper discusses, firstly, the multiple layers of uncertainty presenting barriers to adaptation, and secondly, how cross-scale influences and perceptions of federal land management and Colorado water law situate adaptation in Grand County. We utilize the paired conceptual toolkit of adaptation pathways and envelopes to better understand both the capacity of local actors to pursue adaptation and the broader processes enabling and constraining adaptation options. These concepts situate adaptation within longstanding insights from social theory to enable more nuanced theorization of the processes structuring adaptation and adaptive capacity.

Literature review

Climate adaptation is commonly conceptualized as an adjustment in response to observed or expected changes associated with climate change (Adger et al. 2005; IPCC 2001). However, recent scholarship acknowledges the interacting non-climatic processes influencing adaptation and how adaptation encompasses short-term coping strategies and longer-term transformation to address concerns beyond climate change (Moser and Ekstrom 2010). Thus, it is important to situate adaptation within interacting political, economic, institutional, and biophysical processes (Thornton and Manasfi 2010; Moser and Ekstrom 2010). These processes both enable and constrain adaptation in the context of cognitive, social, and institutional barriers (Moser and Ekstrom 2010; Stafford Smith et al. 2011), including political ideology (Kahan et al. 2011), risk denial (Adger et al. 2009), apathy (Jones and Boyd 2011), lack of knowledge, lack of resources (especially financial resources), insufficient leadership and political will (Archie 2013; Measham et al. 2011), and competing priorities (Measham et al. 2011; Few et al. 2007).

Recognizing this complexity, the adaptation pathway metaphor depicts adaptation as a continual process of change and response in relation to interacting climatic and non-climatic processes (Wise et al. 2014; Haasnoot et al. 2012; Stafford Smith et al. 2011; Dow et al. 2013). This reframes adaptation as a journey through a dynamic system, with many possible planned or unplanned routes and junctions. Pathways focus on integrating incremental adaptation to proximate stressors with more transformative social change (Wise et al. 2014). Adaptation pathways outline a sequence of strategies and policy decisions whereby decision-makers explore different options to address changing environmental and social conditions (Haasnoot et al. 2012).

Adaptive capacity focuses attention on the capacity of different actors, social groups, and institutions to pursue adaptation. Adaptive capacity is mediated by the availability and distribution of resources and technology, the structure of institutions and governance, levels of social and human capital, knowledge generation and management, and perceptions of agency, efficacy, and risk (Yohe and Tol 2002; O'Brien and Hochachka 2010). Both adaptation and adaptive capacity are scale and context specific, shaped by interacting local, regional, national, and global processes (Adger and Vincent 2005). Because local actors are embedded within these processes, local adaptation actions are constrained or enabled by policies, institutions, and social norms operating at multiple, interacting scales (Adger et al. 2005; Dovers and Hezri 2010; Thornton and Manasfi 2010). Because a pathways approach situates adaptation within dynamic, interacting social and ecological processes, it explicitly acknowledges how these processes structure both adaptation and vulnerability (Downing 2012).

If adaptation is social practice, it is constituted by both agency and structure (Giddens 1984). When mobilizing various adaptive capacities, adaptation actors are agents of change in relation to climate impacts and structural processes. Though the literature acknowledges the local and non-local processes influencing adaptive capacity, most definitions emphasize the agency of local adaptation actors. In other words, adaptive capacity is typically about the ability of local actors, as individuals or groups, to marshal knowledge, resources, social networks, and other endowments to enable adaptation. However, as suggested above, numerous context-specific cross-scale interactions influence the ability of local actors to adapt. For example, the global market dictates the price of beef, which affects the capital available to ranchers to invest in water conservation technologies that would help them adapt to drought; endangered species designation limits the types of management actions that can be pursued on critical habitat; federal funding for adaptation enables projects that many communities cannot afford in the context of current revenue streams; lawsuits that hold government agencies liable for not adapting to climate change, if successful, would reshape the legal environment within with federal land managers consider adaptation. Consequently, we believe it is important to have the conceptual tools to distinguish between the cross-scale processes shaping the agency of adaptation actors.

While it is critical not to depict local actors as "powerless spectators" (Fabricius et al. 2007), it is equally problematic to imply that extra-local barriers can be addressed

by simply building local capacity. The transformative capacity of adaptation actors is constrained by various social structures, some of which exist beyond their control (Dyck and Kearns 2006). In short, lumping together the broad suite of resources and endowments that create adaptive capacity conflates structure and agency, constraining our analytical capacity to tease these apart and understand how they interact. Consequently, we recommend conceptually pairing adaptive capacity with an "adaptation envelope" to acknowledge the multi-scaled social structures creating and reinforcing vulnerability and adaptive capacity (and thus adaptation). This creates analytical space to envision how potential adaptation pathways might be opened or closed by structures that are often beyond the influence of local actors. We propose to use the concept of adaptive capacity to envision agency and the concept of an adaptation envelope to understand structure. Together these two terms help to more effectively situate adaptation.

Situating adaptation also requires understanding the ways in which adaptation envelopes change over time. The interplay between structure and agency enables actors to imagine and actualize alternative futures within a dynamic context that includes a past, present, and future (Emirbayer and Mische 1998). The temporal dimension of an adaptation pathway enables us to consider a dynamic interplay between structure and agency, envelope and capacity (see Fig. 1). The emphasis on the ability of agency to influence structure distinguishes a pathway from a path dependency because, in addition to implementing substantive adaptation actions, actors can address constraints operating at multiple scales thus expanding the adaptation envelope.

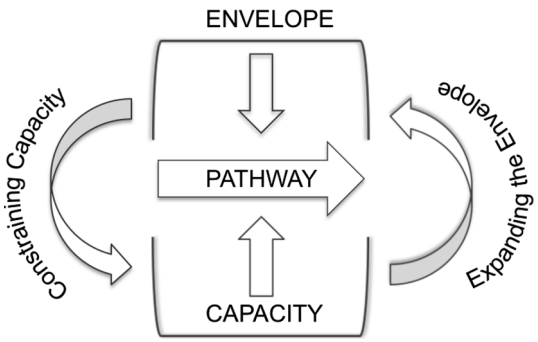

Fig. 1 The adaption envelope. Adaptation envelopes enable and constrain the capacity of local actors to respond to climate change. They shape both the decision space and implementation. Envelopes are created by interacting local and extra-local cultural, economic, political, and institutional processes. Because these processes make some actions possible while creating barriers to other actions, they support and bound adaptation, greatly influencing adaptation pathways. But these constraints are not stable, both local and non-local actors can sometimes expand the envelope. Expansion of the adaptation envelope may lead to improved adaptation outcomes because local actors have a broader set of pathways to pursue

Adaptation pathways also confront decisions with long time frames presenting challenges related to uncertainty, conflict, and controversy (Few et al. 2007; Dessai et al. 2009; Stafford Smith et al. 2011). In particular, long time frames increase the number and types of uncertainties involved in adaptation decision making because of the difficulty of predicting the interactions of various processes over long temporal scales. Robust decision making is often invoked as a way to overcome uncertainty, since robust decisions are believed to work across numerous future scenarios and often focus on no-regrets and reversible actions that preserve a diversity of response options (Hallegatte 2009). Uncertainty can inspire reactive approaches to adaptation, as decision-makers are reluctant to act with insufficient knowledge. However, there is a growing concern that small adjustments and coping responses will be insufficient, leading to calls for anticipatory and transformative adaptation (O'Brien 2012; Pelling 2011; Stafford Smith et al. 2011).

The complex, dynamic, and uncertain context of adaptation requires governance that supports actors to connect adaptive capacity to adaptation pathways (after Adger et al. 2005). Cross-scale interactions necessitate coordination across land tenures, communities, ideologies, and institutions at multiple scales (Wyborn and Bixler 2013). However, adaptation governance, the processes, policies, and structures whereby adaptation decisions are made, must confront potential conflicts between public and private actors, and the uneven distribution of costs and benefits. Adaptation governance operates across multiple scales, as it is shaped by national and international policies, government and non-government actors, and can take on diverse configurations depending on the context and actors involved. Further, the social and biophysical processes operating at different scales require different adaptation responses, increasing the complexity of cross-scale adaptation (Adger et al. 2005). These challenges lead Adger et al. (2005) to suggest that adaptation must consider the dynamic complexity of cross-scale governance.

Through our case study, we examine the ways that different actors envision the complex terrain of adaptation, especially in the context of past environmental change, uncertainty about future climate impacts, and cross-scale governance dynamics.

Methods

This research utilized narrative scenarios of landscape change in interviews and focus groups to discuss local climate change impacts and adaptation options. Scenarios are plausible depictions of how the future might unfold (Berkhout et al. 2013). Narrative scenarios of landscape-

scale ecological change in Grand County were developed based on downscaled climate projections (Dobrowski et al. 2013) and changes to terrestrial and aquatic ecosystems predicted as a result of these projections (Clow 2010; McWethy et al. 2010; Ray et al. 2008; Schoennagel et al. 2012). These scenarios highlighted certain aspects of uncertainty in our current predictive capacity, which primarily exist with regard to the nature, amount, and timing of precipitation as well as the nature and amount of inter-annual variation. We also integrated information on fish response to expected changes in temperature and flow (Tetra Tech et al. 2010; Colorado Parks and Wildlife unpublished data) and cutthroat trout conservation status (Williams et al. 2009). The scenarios were developed by three ecologists and a hydrologist and then reviewed by seven scientists with regional expertise. The scenarios represent a range of possible futures over a 20-year time horizon: a hotter drier future (scenario 1: Some Like it Hot); a warmer future where annual precipitation remained the same, but transitioned to more intense winter precipitation events (scenario 2: The Seasons They are a Changing); and high inter-annual variability, with strings of hot dry years followed by extreme cold and wet years (scenario 3: Feast or Famine). These scenarios are similar to those used by the US National Park Service in scenario planning (see Chapin et al. 2007 for more detail) and are designed to make local climate change impacts more tangible, while explicitly acknowledging uncertainty (Tompkins et al. 2008).

We conducted in-depth, semi-structured interviews with 26 adaptation actors, including state and federal land managers ($n = 7$), private landowners ($n = 5$), business owners ($n = 4$), recreation operators ($n = 7$), local government staff ($n = 2$), and an elected official ($n = 1$). Participants were selected using purposive sampling with the goal of ensuring that the primary categories of adaptation actors were included. Everyone who was invited agreed to participate.

The scenarios were used as a platform for participants to envisage future climate impacts in Grand County. In contrast to other scenario-based methodologies (Ebi et al. 2014; Gidley et al. 2009; Ozkaynak and Rodriguez-Labajos 2010) and planning tools (Goodier et al. 2010; Hallegatte 2009), our scenario-building process moved from individual interviews to small focus groups and finally a large community meeting. We started with individual interviews in order to obtain diverse views on local climate impacts and possible adaptations, without the social pressure present in the focus group setting, and to allow sufficient time for individuals to explore in depth the implications of the different scenarios. The results from the individual interviews allowed subsequent focus groups to explore possible responses in greater detail (since these responses were integrated into the scenarios between the interviews and the focus groups—see next paragraph for more information). Moving from individuals to groups of similar participants also allowed us to examine the relationships between individual and collective responses, including the possible tensions and conflicts between responses at different scales. Additionally, because the scenarios themselves were not "end products" or "goals," but rather elicitation tools designed to reveal adaptation processes, we were able to structure the research process to scale up from individuals to groups to the broader community, rather than starting with more inclusive meeting, which might be required in a planning context.

The initial individual interviews explored views on past environmental change, the risks and vulnerabilities associated with each scenario, adaptation decision making, and adaptive capacity. During these interviews, participants were asked what actions they might take in response to each scenario. Interviews were rapidly analyzed to identify these actions, and all three scenarios were revised to incorporate potential responses by individuals, groups, and institutions. During the revision process, ecologists examined potential responses and the likely ecological implications of these responses were also included in scenario revisions. Moreover, revisions integrated different economic trajectories that participants perceived to be likely in the context of the three scenarios, with scenario one leading to a stable economy, scenario two supporting increased economic development, and scenario three leading to economic decline.

In five focus groups, the revised scenarios were used to explore the challenges and opportunities associated with the scenarios, synergistic or conflicting responses and adaptations, the roles of different actors, possibilities for collective action, governance issues, and how to move forward in the context of uncertainty. Focus groups included seven past interviewees and 15 new participants, including state and federal land managers ($n = 3$), private landowners ($n = 5$), summer ($n = 5$) and winter ($n = 3$) tourism businesses, and a local sustainability group ($n = 6$). A final "community meeting" ($n = 17$) discussed emergent research findings and perspectives on adaptation governance. Ten participants attended the meeting from the interviews and focus groups and seven were new to the study.

Interviews and focus groups were recorded, transcribed verbatim, and coded in NVIVO 9.2. We used NVIVO's matrix coding queries and framework matrices to enable comparative analysis across theoretical and empirical material. Matrix displays cross two or more variables to aid systematic exploration of the data, while visual displays

support exploration of the relationships between core concepts (Miles and Huberman 1994). Analysis presented here draws on the intersection of three thematic coding families (adaptation, uncertainty, and governance), with a set of analytical codes concerning scale and agency. Scale here is conceptualized as spatial, temporal, or jurisdictional units of analysis (Gibson et al. 2000), while agency is the capacity of individuals to act as informed by past events, current conditions, and future orientations (Emirbayer and Mische 1998). Through an iterative analytical process that conceptualized theoretical concepts and empirical findings in relation to one another (Layder 1998), our analysis focused on the ways in which participants conceptualized their agency in relation to temporal and jurisdictional scale. We did not set out to examine concepts of adaptation pathways and envelopes, rather we came to these conceptual metaphors through the analysis, finding that they provided explanatory power within this empirical context. Data excerpts are presented below to both illustrate views shared by a number of research participants and serve as evidence for later conclusions.

Study site

Grand County, Colorado, like much of the Interior West, has an amenity-driven economy and a complex mix of land ownership and jurisdiction. The economy focuses largely on summer and winter tourism and recreation, which exists alongside ranching, forestry, and mining. Grand County is 75 % federal lands that are managed by the National Park Service and the US Forest Service in accordance with a range of federal laws, including the *National Environmental Policy Act 1969* (NEPA), the *Clean Water Act 1977* (CWA), and the *Endangered Species Act 1973* (ESA). State lands and wildlife in Grand County are managed by Colorado Division of Parks and Wildlife, with the exception of endangered species and wildlife, which are managed by federal agencies. There are also large cattle ranches, a growing number of small parcels in the wildland urban interface, and three ski resorts, all managed by private owners. Municipal and county officials and agencies oversee local services and planning and manage some small parks. While there are 14,000 permanent residents in Grand County, over 60 % of the houses have absentee owners (NWCCG 2006). We focused on the eastern side of the County to examine diverse economic and livelihood strategies at the headwaters of the Colorado River.

Mountain communities reliant on winter recreation and tourism are believed to be particularly vulnerable to climate change (Archie 2013) due to increased winter rain, declining snow depth, and shorter snow seasons (Knowles et al. 2006). Increases in fire size and frequency, lower late summer stream flow, and more pronounced drought also impact tourism, forestry, and ranching. In Grand County, two climate-influenced stressors are particularly significant: water availability and forest pathogens. In the early 2000s, Grand County experienced a major outbreak of mountain pine beetle (Dendroctonus ponderosae), resulting in massive forest dieback in lodgepole pine (Pinus contorta) stands. There have been some informal collaborative efforts to address the bark beetle outbreak, and agencies and local governments participate in Colorado-wide collaborations related to bark beetles. The County is challenged by substantial out of basin water transfers, with approximately 70 % of the county's water diverted across the Continental Divide to the "Front Range" communities of Denver, Boulder, Fort Collins, and Colorado Springs. These diversions could increase to 80 %. Colorado water law governs the rights and use of water in the County, while regional water conservancies are responsible for management. Formal negotiations between Grand County communities and water rights holders on the Front Range have occurred in the last 10 years, resulting in some mitigation funds to address impacts of diversions on aquatic species.

Results

Past experience of change and views on future adaptation

Consistent with previous studies (Smith and Leiserowitz 2012), Grand County residents viewed climate change as a distant future problem yet to impact them. However, they simultaneously acknowledged local variability and change, suggesting that they had "been through all three of the scenarios in the last 20 years." Resident experiences of the beetle outbreak, water diversions, and life in a variable climate shaped their perspectives on adaptation, adaptive capacity, and how their communities might respond to the changes depicted in the scenarios.

Many residents argued that change would be "gradual" and "slow," enabling a "transition period" during which they would adapt. These residents viewed adaptation as entirely unplanned, almost unconscious. According to one resident, "so long as change is relatively slow … people are going to adapt and may not even realize they are adapting." Another suggested that because people slowly adjust, awareness of specific changes, such as lower levels of winter precipitation and early spring snowmelt, would not change one's "approach to life." Citing the beetle outbreak, this real estate agent suggested that adaptation:

> Happens gradually and humans react according. Even if we had known a pine beetle epidemic was coming,

> I don't know what we could have done differently … if you look at the vastness of what we have here, to try to manage these resources … you'd probably get pushback if you wanted to do something crazy.

Even with foresight, he believes community support for dramatic, proactive action would be minimal.

Residents largely characterized adaptation as reactive, incremental actions taken as changes unfold. As examples, they cited recent responses to variable climatic conditions: ski resorts focusing on year-round recreation and communities emphasizing summer activities such as mountain biking. One business owner waited to "see what kind of winter it was" before investing in new equipment, hiring more staff, and upgrading infrastructure. With this coping strategy, his business survived boom and bust years without over-committing limited resources; however, he was unwilling to plan beyond a few years out. Because residents wanted to respond to observed change, the 20-year time horizons utilized in the scenarios were largely irrelevant to decision making.

Residents most concerned about climate change focused on mitigation and improved public transportation. Suggestions for adaptation included communication and education, infrastructure improvements, adjustments in agriculture and land management, and small-scale actions focused on tinkering with existing systems and structures. Mitigation and adaptation were almost always explicitly situated within local economic development concerns. Residents cited a countywide economic development strategy as critical to improve Grand County's capacity to respond to future change. Despite faith in his community's capacity to act, this local official sees economic challenges as a barrier to proactive adaptation:

> If you're asking can we or will we, that's probably two different things. I think yes, we can. Will we? Is it a priority right now? Probably not … I don't think there would be a priority for something that they don't even know, that's 20 years out. Probably most people are too concerned with if they're going to be able to have a viable business next week than if they're going to have something down the road.

Accordingly, current economic challenges overwhelmed support for proactive actions that anticipated future change. A handful of residents proposed potentially transformative actions focused more on mitigation than adaptation, including investments in biomass and solar energy.

Residents described the beetle outbreak as part of a natural cycle of landscape change, suggesting this outbreak prepared the community for future environmental change. They cited "the adaptability" and "resilience" of Grand County residents who were able to "adjust," "be flexible," and "handle whatever is thrown at them." As this public land manager describes:

> we've learned…we're smarter than some of these counties that haven't been hit. They are still in denial. We went through that phase and now we're trying to cope.

Another public land manager, citing the combined challenges of water diversions and the beetle outbreak suggested "people have shown that they are pretty good at responding appropriately." Local responses involved removal of dead trees from private lands, developing community wildfire protection plans, and negotiating improved terms with Front Range water users. Thus, residents believed their experiences of change and variability fostered a capacity to cope with the changes described in the scenarios.

Paradoxically, many suggested that responses to the beetle outbreak came too late to adequately address local impacts. By responding with past events in mind, this land manager believed the agencies underestimated the scope of the outbreak and were "always a day late and a dollar short." This resident describes her disappointment with this approach, saying:

> I look across Lake Granby to the national forest and just a sea of dead trees … our public agencies … I give them a big fat F, failed, in timber management. The effects of this pine beetle epidemic would not be nearly what they are now if we had enough timber harvesting on public land … they haven't been as adaptable and they haven't changed fast enough.

Many suggested that "nothing happens here unless something big changes." This federal land manager explains this process in the context of wildfire:

> I think seeing is believing … trying to encourage folks to come up with good plans in reaction to wildfire, I had very slow progress. But when we had a fire here in December, which moved three miles in 35 min and forced evacuations, we got all kinds of folks at the table wanting to do something different. Unfortunately, folks often are most motivated in the immediate shadow of an emergency.

Climate impacts were envisioned as gradual and diffuse, but residents argued that a dramatic event would be required to catalyze action, especially in the context of more immediate economic and environmental concerns. Even when presented with three scenarios of future change, many residents did not see the kinds of local impacts that would motivate adaptation.

Multiple layers of uncertainty

Residents envisioned multiple types of uncertainty shaping climate adaptation, well beyond typical questions about scientific certainty and anthropogenic climate change (see Table 1). Depending on their perspective on climate change, residents perceived local variability as either a window into future anthropogenic climate change or part of ongoing cycle of natural variability and change. Residents often conflated variability and uncertainty, suggesting that variability in the feast or famine scenario created greater uncertainty than the other scenarios, which were viewed as more predictable. While inter-annual variability creates some uncertainty related to the upcoming year, the excerpts in Table 1 suggest that residents were also cognizant of uncertainty about how climate change would play out at a local scale, about how individuals, businesses, or land managers would or should respond, and about the feasibility and efficacy of various responses.

Table 1 Multiple layers of uncertainty identified by Grand County residents

Type of uncertainty	Quote
Uncertainty about the cause of climate change (is climate change anthropogenic?)	Solar activity is off the charts … that's a big contribution to our warming temperatures
	I'm not denying the fact that there may be climate change … What I'm in disagreement about is what's causing it … we're not big enough and powerful enough to change the entire climate, good or bad
Uncertainty about which scenario describes the future (how do you know which future to adapt to?)	I don't have any idea what's going to happen in the long term, 50 years from now, 100 years from now, who knows what the temperatures are going be like? I don't know that they actually can predict all that. It could be the opposite of what they're saying
Uncertainty emerging from variability (how do you plan under the feast or famine scenario?)	I think the unpredictability in that one [scenario three] would be hardest for everybody and not just our business but everybody in the county to just cope with, just not having a way to predict how many ups you're going to have and then how many downs you're going to have in a row
Uncertainty regarding how to respond to change (how do we adapt even if we know what changes are coming?)	How would we respond to these changes from a management standpoint? I guess I'm not sure
	I don't know how the world will react … It's kind of disconcerting to the general person because they don't know what to do. They just don't know what to do

Residents viewed these multiple layers of uncertainty as barriers to adaptation. Here, one public land manager discusses these challenges:

> In these scenarios there's a lot of 'what ifs.' People can get behind something that they know, "Okay, if you don't do A, B, C you're going to end up at D." These scenarios you can't say that. … I've seen that in order to get the public and our agency behind something people need more concrete evidence because there's always going to be the naysayers, "Do you really have to do that?" I think that would be a barrier for sure.

Land managers expressed concerns about public support for adaptation given uncertainty about local futures and the efficacy of adaptation actions.

Even those acknowledging a need for "proactive" adaptation suggested, it would be "unwise" to adapt given future uncertainty. According to this public land manager:

> I guess we always should be proactive and maybe prepare for the inevitable but I don't know that it would be prudent to try to predict what is going on right now. I think we manage the way we currently do until we see that something's changed.

This wait-and-see approach was also evident among residents who were aware that many adaptive strategies require long-term investments. As this local official and rancher suggests:

> If I knew there was going to be this scenario with this huge runoff and then dry, I would want to work on water storage now. That's a big process. Even the smaller ones you would do on your own private property, it still takes some time to put that in place … Big water storage projects take decades to get in place … So tell me which one we're going to get, and I'll start planning.

This echoes many others who suggested that more accurate predictions could provide the certainty needed to invest in adaptation. As this public land manager points out:

> I don't think that there are all kinds of barriers that would keep us from responding. It's just being aware that that's the scenario you've got. That would be the thing I think would ultimately be hard, to know that you're in this scenario. But if you knew you were living in it, you could figure out how to respond to it,

how to work with businesses, whether it's a grazing permitee or a snowmobile guide or a ski area.

That said many residents were skeptical that the certainty necessary to take long-term actions would be forthcoming. In the absence of certainty, residents focused on the need for flexible and adaptable management strategies, including "contingency planning" that would enable them to "seize opportunities" as they appeared. Framing adaptation as contingency planning is akin to an adaptation pathway. As this resident says, "if this happens you do A, if that happens, then do B." Residents believed economic diversification could buffer the impacts of future changes to the existing summer and winter tourist economy. As described above, variable economic and climatic conditions appear to have created a risk-averse culture where individuals and business owners save money made during the "feast" to live through the "famine." Residents operating at the margins were unwilling to invest in adaptation actions to address admittedly uncertain futures. Thus, multiple social, economic, and ecological uncertainties create substantial barriers to proactive adaptation.

Governance and cross-scale interactions I: water diversions

Residents readily discussed a range of cross-scale drivers shaping Grand County's adaptation envelope, in particular the water diversions to the Front Range and federal land management. Policy at the state level was believed to influence adaptation, with many residents arguing that, given Colorado water law, "you have to include the Front Range" in the scenarios. Residents believed that climate change and water diversions together would exacerbate tensions with the Front Range and amplify climate impacts in Grand County. As this hunting outfitter argued:

> They own the water. As it gets drier, they're going to take the water. The people on the Front Range just feel like they have a right. "This is our water. This is the city. This is Colorado. The mountains up there, they'll get by."

Many recognized that support for building reservoirs in Grand County would be futile without locally held water rights. This resident summed up the situation, saying "if you don't have the water rights, you're not going to be able to build a pond"; while another suggested that despite "having all these people on board to create the infrastructure, we don't have the laws to support it." This resident described the power imbalance between Grand County and the metropolitan water boards on the Front Range, saying:

> They can get away with things because they have enough money and power and lawyers who can beat everyone else … It's a disgrace what Denver Water Board and Northern Water Conservancy are doing to this county by taking all the water.

Most residents were deeply cynical about the power dynamics underpinning current discussions of increased water diversions, recognizing that without major but unlikely changes in Colorado water law, Grand County would be unable to retain more water. Consequently, certain adaptation pathways (e.g., additional water storage to address summer drought, preserving stream habitat to ensure healthy fish populations to attract tourists) are not possible given the constraints of the water diversions, leaving many feeling powerless to respond to drought.

Governance and cross-scale interactions II: federal land management

Consistent with Archie's (2013) research in southern Colorado, residents believed that federal land management affected, and often constrained, adaptation decisions. Because Grand County is 75 % federal lands, many residents argued that the local economy was highly dependent on federal decision making. As this resident stated:

> Everything is dependent on the government management of the park and the Forest Service and the wildlife, everything, because this whole economy countywide … is built on how well that goes.

A myriad of concerns about federal land management, including worries about powerful vested interests, the sense that decisions had already been made, and a feeling that public views were not considered undermined trust in decision-makers to manage public lands in accordance with the needs and values of the local community. Many believed this trust was central to adaptation. As this local official explains:

> I would want the community to trust their leaders to make a decision but also have those decisions based on local resources, community input, knowledge, collaboration, and they'd be able to take some action when it's necessary on a timely basis. That seems to be one of the failures of government. Sometimes they do the right thing, it's just 5 years too late.

More generally, residents attributed their lack of trust in the ability of public agencies to high turnover of staff, policies, and programs; a lack of transparency; and poor forest management practices.

Many residents viewed the regulations governing land management as a barrier to effective decision making. As one private land owner expressed:

> It is virtually impossible for any government agency to allow for anything to happen … there is a whole lot of talking going on and not a lot of anything accomplished. Everything is so incremental. Part of it is because of the rules and regulations, the labyrinth, it is nuts.

Residents lamented the lengthy processes involved with institutional decision making. Public land managers supported this view, suggesting that complex situations involving multiple entities (federal and state land management agencies, private actors, and local governments), regulatory processes (e.g., NEPA, ESA, CWA, and Colorado Water Law), and ecosystem properties (e.g., fire, water, wildlife, and invasive species) were difficult. One rancher illustrated a complex situation, describing lengthy negotiations over access to a particular section of an irrigation ditch because multiple agencies had jurisdiction and private landowners had different priorities. Public land managers cited a number of governance challenges constraining their adaptation envelope: vague agency mandates, insufficient budgets, lack of adequate directives, too few staff, conflicting public opinions, special interest groups, and disconnects between national-level mandates and local concerns. One public land manager pointed to potential restrictions on prescribed burning to highlight the disconnect between local Forest Service staff and higher level agency policy:

> We sit here at the ground level going, 'This is a no-brainer. We don't even have to be worried about this.' And there's people who aren't too far removed from us going, 'We just can't do it.'

Restrictions of this kind were seen to hinder locally salient adaptive responses.

Directives from Washington D.C. and extra-local interests were seen to drive federal land management. Similar to other communities in the Interior West (Yung et al. 2010), some residents questioned whether federal lands should be managed for the benefit of local communities rather than broader national interests. For public land managers, the beetle outbreak brought such divergent priorities to the fore:

> You could have pulled anybody off the street in Grand County and said, 'Should we be doing some timber cutting up here?' and they would have said, 'Hell, yeah, why wasn't it done 10 years ago?' We've had this public acceptance, professional latitude to do our work for a decade or so, but it's going away again. The environmental groups are gaining much more traction, and this comes from Washington D.C. straight to Colorado.

Several land managers expressed concern about waning public support as the beetle "crisis" subsides. For these managers, the beetle outbreak presented more pressing management challenges than climate change. Focusing on immediate needs was not, according to this manager, "sticking our heads in the sand on climate change." Rather he felt that the Forest Service multiple-use mandate and existing laws (the ESA and the CWA) provide an adequate framework to prepare for climate change.

While "immediate needs" took precedence, some land managers wanted to move beyond a "day-to-day" focus. All the land managers spoke of being in the middle "reacting and responding" to the beetle outbreak. Nearly all residents and public land managers positioned themselves within the dominant US Western discourse arguing that fuel reduction is *the* appropriate response to beetle outbreaks. However, they saw fuel reduction and other management actions to create a resilient forest as part of a long-term program to prevent future outbreaks. In this sense, they situated their management within a longer temporal context, as this manager explains:

> You're kind of playing out in the future on the habitat side of it. Trying to make it a better place for whatever species you're managing and you may not see that within your career but we also, on a shorter time frame, have to manage those populations towards that goal so we have a beneficial habitat waiting for them.

This view frames public land management as series of decisions along a particular trajectory, akin to an adaptation pathway. Managers' believed, however, that shortsighted agency policies, and limited budgets and personnel constrained their ability to undertake long-term planning. According to this manager, agency policies related to the beetle outbreak exemplified this problem:

> We've thrown so much money at all these timber sales and all these hazard projects, now everyone's going, 'OK, we're done!' No, we just started. There are so many more things that need to happen. There's a bit of shortsightedness going on. We can't just walk away from this. We need to continue.

Despite the fact that adaptation was repeatedly characterized as reactive, many recognized the need for long-term planning and investment in particular adaptation pathways. Residents also readily identified the ways that federal policies and budgets constrained longer-term adaptation efforts, effectively shrinking the adaptation envelope around collective action to address climate change impacts

on public lands. But overall, residents were deeply skeptical of existing governance processes, citing the dysfunctional bureaucratic mess, cooption by vested interests, reactive management, and the inability to be flexible and adaptive as barriers to effective adaptation. These perceptions created a profound lack of trust in the ability of federal agencies to support the types of coordinated, long-term, and responsive decision making called for in the literature.

Scale and action

The governance issues created by cross-scale interactions related to water and federal lands evoked a range of responses from Grand County residents. A number of residents expressed a lack of faith in water and federal land governance, describing the system as "dysfunctional" and "a bureaucratic mess." Some suggested that they lacked representation, exclaiming that "democracy sucks sometimes" and stating that elected officials "often don't represent the people who elected them" because "the tail wags the dog," suggesting that special or powerful interests dictate outcomes. These residents perceived current decision-making processes as incapable of supporting proactive strategies to safeguard the environment and respond to local needs.

Further, many perceived that extra-local interests and Front Range residents were unconcerned about the local consequences of water diversions and federal land management. Consequently, some argued for increased federal intervention in the management of the Colorado River, while others resisted such intervention, arguing that federal decision-makers lack the local knowledge and experience to intervene effectively. According to one local official:

> I would like the government to leave us alone and let us make more decisions locally … if the people who are the most directly involved have the say over what they can or cannot do, it's always better than somebody that's at some other location, and I'm knocking Washington again. They cannot, no matter how hard they try and how much they say they do, they don't have a feel for what goes on here.

Thus, many residents simultaneously believed that powerful extra-local interests constrained their ability to respond to change and that adaptation assistance from extra-local entities was undesirable. Regardless of the issue or scale, government intervention incited divisive perspectives, with more politically conservative residents advocating for a smaller government role in adaptation and more politically liberal residents advocating for greater public sector involvement. Many argued that different political ideologies would create disagreement over how to address adaptation.

Divergent perspectives on the efficacy of local adaptation actions can be attributed to different beliefs about the locus of control. Some suggested that the global scale of climate change simply overwhelms the actions available at a local scale, suggesting that adaptation is a "big, steep hill to climb." According to this public land manager:

> There's possibly a feeling that it really doesn't matter what we come up with, that it's not going to make a significant change in the scenario … the solutions are too small for the problem being addressed.

Because of their perceived inability to influence water diversions and federal land management, residents suggested they were "defeated," often expressing a profound lack of agency.

In contrast, others felt that tangible, local, and even individual actions could effectively address local climate change impacts. One resident suggested focusing on "what's in your own backyard, what you can control… small steps can go a long way." For these residents, adaptation required "everybody stepping together" to develop strategies to cope with these scenarios. Residents were proud of cross-jurisdictional and cross-tenure collaborative efforts to address the beetle outbreak. Further, given the power of extra-local interests over water diversions, developing relationships with these actors was, according to one local government employee, the only hope for Grand County:

> The relationship and the understanding we've forged between the east and west slopes. Understanding what we each need and why we are doing our jobs and the respect for each other of what we're doing, but also knowing that if we work together we can do better for both - that's the future.

Relationships between local and extra-local actors were believed to build local capacity to respond to change, with residents suggesting that adaptation would require some form of collective action. However, many wondered whether or not there would be agreement on what type of future Grand County should be striving for and how best to motivate collective action.

Discussion and conclusion

In-depth knowledge of how adaptation is situated in particular contexts is required to fully understand adaptation, enable public engagement, and develop effective governance (Pelling 2011; Bassett and Fogelman 2013). In Grand County, recent experiences with water diversions

and bark beetle outbreaks fostered a high perceived capacity to navigate future change at a local scale. But residents largely viewed adaptation as incremental and reactive adjustments in response to gradual change and were typically unwilling to support proactive measures because of more pressing economic concerns. Further, adaptation in Grand County faces significant challenges due to multiple interacting uncertainties, conflicting ideologies about the role of the public sector, legal frameworks that remove key resources from the landscape, potentially unresponsive federal land management, and local resistance to transformative change. Thus, it is difficult to imagine Grand County communities moving beyond coping strategies and incremental adaptation to the anticipatory and transformational change discussed in the academic literature.

Framing climate adaptation as an adjustment in response to climate stimuli narrows the scope of adaptation options and misses the broader social–ecological context within which adaptation occurs (O' Brien et al. 2007; Bassett and Fogelman 2013). In this case, residents' overwhelming desire to focus on current economic and environmental processes points to the importance of situating adaptation within the present. However, focusing on current challenges risks neglecting actions to address potentially transformative future changes extending beyond current decision-making time frames (Stafford Smith et al. 2011). Further, many adaptation strategies suggested by Grand County residents, including economic diversification, infrastructure upgrades, more responsive public lands decision making, and increased agricultural productivity, require both incremental adjustments to current stressors and longer-term, cross-scale transformative actions. Residents' perceptions that political ideologies and visions for the future would likely incite conflict highlights the importance of attending to questions concerning potentially divergent ideas about which adaptation pathway to pursue.

Despite focusing on incremental adjustments that do not challenge the local status quo, Grand County residents outlined how extra-local forces shaped their sense of agency while constraining local adaptation. Residents focused on Colorado water law and regulations governing federal lands to illustrate how powerful cross-scale institutional processes structured their adaptation envelope. Conceptualizing adaptation as a pathway can bridge incremental and reactive adjustments to long-term planning and transformative action (Stafford Smith et al. 2011). Because Grand County residents already situate adaptation within current climatic and non-climatic stressors and identify a number of cross-scale interactions that influence their adaptation envelope, the pathways bridge is particularly relevant: adaptation as a pathway can connect those continual, gradual responses to broader discussions of adaptation decision making and governance. Thus, we believe that the pathways concept could provide an important platform from which to begin a conversation about adaptation in a place like Grand County, where residents are unwilling to look beyond current management challenges.

Theoretically, pathways also create space to envision individual and collective agency. As actors and institutions respond to different events, decisions, and stressors, they can alter pathways accordingly (Wise et al. 2014). Viewing adaptation as a pathway rather than a response focuses attention on the social, economic, and institutional processes creating both vulnerability and adaptation (Downing 2012), what we call the adaptation envelope (see Fig. 2). While the concept of adaptive capacity illuminates the multiple resources and endowments available to pursue particular adaptation pathways, the case of Grand County illustrates that local adaptive capacity may be unable to alter the powerful extra-local structures that constrain or even block adaptation. Thus, rather than simply emphasize building local capacity, we conceptualize an adaptation envelope that shapes adaptation pathways, that can expand or contract over time, and is influenced by both local and extra-local actors (see Fig. 2). Expanding the adaptation envelope creates space for local actors to pursue alternative pathways; the efforts of Grand County residents to negotiate with Front Range water rights holders are just this sort of initiative (see Fig. 3). Adaptive capacity, then, is the capacity to pursue a particular pathway and to enlarge a particular envelope.

Adaptation occurs within the context of multiple uncertainties, increasing the complexity of the decision space. Because uncertainty in climate projections is one of many unknowns (Stafford Smith et al. 2011), recognizing

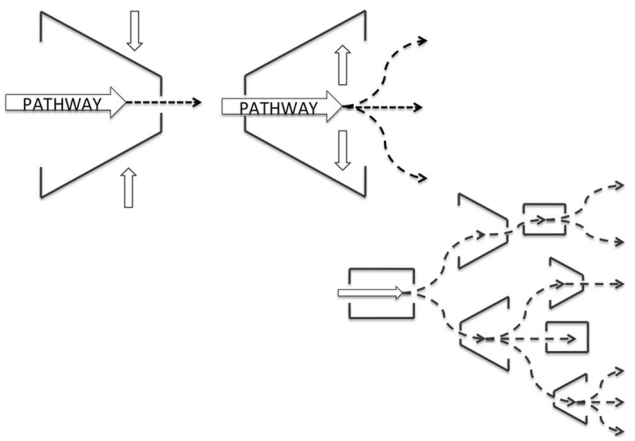

Fig. 2 Adaptation pathways and envelopes through time. Adaptation envelopes both enable and constrain adaptation options (*image on top left*). As these envelopes expand and contract, as a result of local and non-local processes, some adaptation pathways are opened or diversified while others are closed off (*bottom right*)

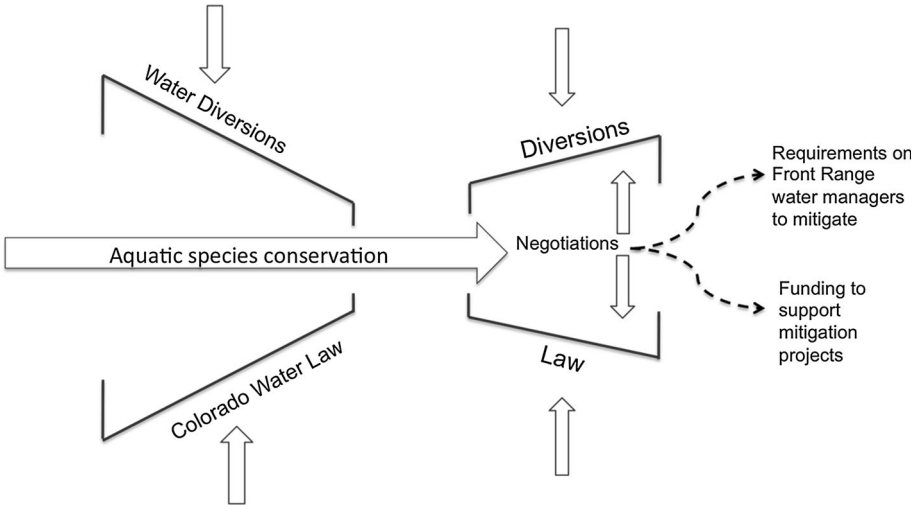

Fig. 3 Envelopes and pathways in action. Colorado water law enables substantial water diversions from Grand County to Front Range communities, which limits possible pathways for managing in-stream flow to conserve aquatic species in the context of future drought. However, negotiations between Grand County public land managers, local government officials, and Front Range water managers expand the adaptation envelope through requirements and funding for mitigation, enabling local actors to pursue new adaptation pathways

the "explosion of uncertainties" (Dessai et al. 2009) has been proposed to help adaptation actors move beyond the perception that uncertain science is a barrier to climate action (Adger et al. 2009). In this study, we found that adaptation actors were readily willing to engage in a discussion about diverse uncertainties at play in adaptation. However, recognizing this "explosion of uncertainties" reinforced, rather than overcame their perception of uncertainty as a barrier to action. Since perceptions of risk and uncertainty are rooted in culture, values, and politics (Bammer and Smithson 2008), effective adaptation must be situated within the ways that actors navigate the specific uncertainties they face. Better science and management cannot address deep uncertainties; these require ethical and political judgments about what should be done and how uncertainty should be managed (Kasperson 2008). Residents' suggestions of how to manage uncertainty: flexibility, diversity, adaptability, and contingency planning, challenge existing decision-making processes. This is particularly salient for federal land management, which oftentimes requires "concrete" evidence to support particular courses of action and a final decision to ensure accountability and procedural fairness (Tarlock 1994). Given the ways that uncertainty challenges current governance, adaptation efforts need to focus on the decision-making *processes* that enable institutions to develop legitimate strategies in the context of uncertainty (Buuren et al. 2013; Camacho 2009).

Adaptation pathways conceptualize adaptation as an ongoing process rather than a discrete action, highlighting the critical role of policy and governance. Focusing on institutions and actions shifts the emphasis from what should happen to how it might be achieved (Dovers and Hezri 2010). Moreover, understanding governance processes as both constraining and enabling adaptation is key to conceptualizing and expanding the adaptation envelope. Because adaptation governance operates at multiple scales, a pathways approach must consider the structures, relationships, and processes to connect actors and decision-making across scales.

While the resilience literature draws attention to the cross-scale interactions shaping governance (Adger et al. 2005; Folke et al. 2005), we suggest that many conceptualizations of adaptive capacity conflate a multitude of enabling and constraining factors from cognitive processes to macro-scale political economic structures with little attention to their interactions. This conceptual "lumping" limits analyses of how power and agency affect the interactions of these processes across different scales and shape the ways local scale actors navigate environmental change (Cote and Nightingale 2011). Focusing on local capacity implies that actors can marshal individual and collective agency to address barriers, without acknowledging the ways that extra-local processes structure adaptation envelopes.

We hypothesize that the capacities and strategies associated with implementing interventions at a local scale are likely to be very different than those needed to bring about broader institutional change. This contention points to the need for future research to identify and differentiate between actions targeted at building adaptive capacity at a local scale versus expanding an adaptation envelope, which may require actions at regional, national, or even international scales. Conceptualizing adaptive capacity, pathways, and envelopes in relation to one another provides insight into the types of policy interventions needed to support adaptation at different scales, without assuming that local capacity building alone can overcome broader political economic structures. Providing greater specificity regarding the differences and interactions between these concepts enables practitioners and policy makers to develop more targeted interventions focusing on particular needs and the appropriate scale(s) to address those needs.

Many questions remain. How can local actors work across scales to expand adaptation envelopes? How does partial knowledge of and conflicting views on a range of structural forces influence the ability of local actors to affect the adaptation envelope? What kinds of processes will enable actors to move from one pathway to another? What sorts of legislative and regulatory mechanisms will promote the flexibility and accountability necessary to move along a pathway over time? How can pathways help connect incremental, reactive approaches to long-term planning and transformative change? Research on these and other questions will help move the pathways idea from abstract metaphor to institutionalized decision-making practice (Dovers and Hezri 2010).

Acknowledgments We wish to thank Grand County residents who participated in interviews and focus groups. We are grateful to the USDA Forest Service Rocky Mountain Research Station for financial support and for the contributions of Cory Cleveland, Solomon Dobrowski, Lisa Eby, Shannon McNeeley, and Erin Towler.

References

Adger WN, Vincent K (2005) Uncertainty in adaptive capacity. C R Geosci 337(4):399–410

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15(2):77–86

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Change 93:335–354

Archie KM (2013) Mountain communities and climate change adaptation: barriers to planning and hurdles to implementation in the Southern Rocky Mountain Region of North America. Mitig Adapt Strat Glob Change Online First. doi:10.1007/s11027-013-9449-z

Bammer G, Smithson M (eds) (2008) Uncertainty and risk: multidisciplinary perspectives. Earthscan, London

Bassett TJ, Fogelman C (2013) Déjà vu or something new? The adaptation concept in the climate change literature. Geoforum 48:42–53

Berkhout F, Hurk B, Bessembinder J, Boer J, Bregman B, Drunen M (2013) Framing climate uncertainty: socio-economic and climate scenarios in vulnerability and adaptation assessments. Reg Environ Change. doi:10.1007/s10113-013-0519-2

Buuren A, Driessen P, Teisman G, Rijswick M (2013) Toward legitimate governance strategies for climate adaptation in the Netherlands: combining insights from a legal, planning, and network perspective. Reg Environ Change. doi:10.1007/s10113-013-0448-0

Camacho AE (2009) Adapting governance to climate change: managing uncertainty through a learning infrastructure. Emory Law J 59:1–55

Chapin SF, Zavaleta ES, Welling LA, Deprey P, Yung L (2007) Planning in the context of uncertainty: flexibility for adapting to change. In: Cole DN, Yung L (eds) Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington, pp 216–233

Clow DW (2010) Changes in the timing of snowmelt and streamflow in Colorado: a response to recent warming. J Clim 23(9):2293–2306

Cote M, Nightingale AJ (2011) Resilience thinking meets social theory: situating social change in socio-ecological systems (SES) research. Prog Hum Geogr 36(4):475–489

Dessai S, Hulme M, Lempert R, Pielke RA (2009) Do we need better predictions to adapt to a changing climate? Ecos 90(13):111–112

Dobrowski SZ, Abatzoglou J, Swanson AK, Mynsberge A, Greenberg JA, Holden Z, Schwartz MK (2013) The climate velocity of the contiguous United States during the 20th century. Glob Change Biol 19(1):241–251

Dovers SR, Hezri AA (2010) Institutions and policy processes: the means to the ends of adaptation. Wiley Interdiscip Rev Clim Change 1:212–231

Dow K, Haywood BK, Kettle NP, Lackstrom K (2013) The role of ad hoc networks in supporting climate change adaptation: a case study from the Southeastern United States. Reg Environ Change 13(6):1235–1244

Downing TE (2012) Views of the frontiers in climate change adaptation economics. Wiley Interdiscip Rev Clim Change 3(2):161–170

Dyck I, Kearns RA (2006) Structuration theory: agency, structure, and everyday life. In: Aitken S, Valetine G (eds) Approaches to human geography. Sage, London, pp 86–97

Ebi Kristie et al (2014) A new scenario framework for climate change research: background, process, and future directions. Clim Change 122:363–372

Emirbayer M, Mische A (1998) What is agency? Am J Sociol 103(4):962–1023

Fabricius C, Folke C, Cundill G, Schultz L (2007) Powerless spectators, coping actors, and adaptive co-managers: a synthesis of the role of communities in ecosystem management. Ecol Soc, 12(1):29. http://www.ecologyandsociety.org/vol12/iss1/art29/

Few R, Brown K, Tompkins EL (2007) Public participation and climate change adaptation: avoiding the illusion of inclusion. Clim Policy 7(1):46–59

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive Governance of Social-Ecological Systems. Annu Rev Environ Resour 30:441–473

Gibson CC, Ostrom E, Ahn TK (2000) The concept of scale and the human dimensions of global change: a survey. Ecol Econ 32(2):217–239

Giddens A (1984) The constitution of society. Polity Press, Cambridge, p 417

Gidley J, Fien J, Smith J-A, Thomsen D, Smith T (2009) Participatory future methods: towards adaptability and resilience in climate-vulnerable communities. Environ Policy Gov 19:427–440

Goodier C, Austin S, Soetanto R, Dainty A (2010) Causal mapping and scenario building with multiple organizations. Futures 42:219–229

Haasnoot M, Middelkoop H, Offermans A, van Beek E, van Deursen WP (2012) Exploring pathways for sustainable water management in river deltas in a changing environment. Clim Chang 115(3–4):795–819

Hallegatte S (2009) Strategies to adapt to an uncertain climate change. Glob Environ Chang 19(2):240–247

Intergovernmental Panel on Climate Change (IPCC) (2001) Climate change 2001: impacts, adaptation and vulnerability. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Contribution of working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK

Jones L, Boyd E (2011) Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Kahan D, Jenkins-Smith H, Braman D (2011) Cultural cognition of scientific consensus. J Risk Res 14(2):147–174

Kasperson RE (2008) Coping with deep uncertainty: challenges for environmental assessment and decision-making. In: Bammer G, Smithson M (eds) Uncertainty and risk: multidisciplinary perspectives. Earthscan, London, pp 337–348

Knowles N, Dettinger MD, Cayan DR (2006) Trends in snowfall versus rainfall in the Western United States. J Clim 19(18): 4545–4559

Layder D (1998) Sociological practice: linking theory and social research. Sage, London

McWethy DB, Gray ST, Higuera PE, Littell JS, Pederson GT, Ray AJ, Whitlock C (2010) Climate and terrestrial ecosystem change in the US. Rocky Mountains and Upper Columbia Basin: historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR—2010/260. National Park Service, Fort Collins, Colorado

Measham TG, Preston BL, Smith TF, Brooke C, Gorddard R, Withycombe G, Morrison C (2011) Adapting to climate change through local municipal planning: barriers and challenges. Mitig Adapt Strat Glob Change 16:889–909

Miles M, Huberman A (1994) Qualitative data analysis: an expanded source book. Thousand Oaks, California

Moser SC, Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. PNAS 107(51):22026–22031

Northwest Colorado Council of Government (NWCCG) (2006) Transitions in mountain communities: resort economies and their secondary effects. Venturoni Surveys and Research Inc, Dillion

O' Brien K, Eriksen S, Nygaard LP, Schjolden ANE (2007) Why different interpretations of vulnerability matter in climate change discourses. Clim Policy 7(1):73–88

O'Brien K (2012) Global environmental change II: from adaptation to deliberate transformation. Prog Hum Geogr 36(5):667–676

O'Brien K, Hochachka G (2010) Integral adaptation to climate change. J Int Theor Pract 5(1):89–102

Ozkaynak B, Rodriguez-Labajos B (2010) Multi-scale interaction in local scenario-building: a methodological framework. Futures 42:995–1006

Pelling M (2011) Adaptation to climate change: from resilience to transformation. Routledge, London

Ray AJ, Barsugli JJ, Averyt KB (2008) Climate change in Colorado: a synthesis to support water resources management and adaptation. A report for the Colorado water conservation board by the NOAA-CU Western water assessment

Schoennagel T, Veblen TT, Negron JF, Smith JM (2012) Effects of mountain pine beetle on fuels and expected fire behavior in Lodgepole Pine Forests, Colorado, USA. PLoS One 7(1):e30002

Smith N, Leiserowitz A (2012) The rise of global warming skepticism: exploring affective image associations in the United States over time. Risk Anal 32(6):1021–1032

Stafford Smith M, Horrocks L, Harvey A, Hamilton C (2011) Rethinking adaptation for a 4 °C world. Philos Trans A 369(1934):196–216

Tarlock D (1994) The nonequilibrium paradigm of ecology and the partial unraveling of environmental law. Loyola Los Angel Law Rev 27:1121–1144

Tetra Tech, HabiTech Inc., Walsh Aquatics, Inc. (2010) Draft report stream management plan phase 3 Grand County, Colorado. Prepared for Grand Country CO, Colorado

Thornton TF, Manasfi N (2010) Adaptation—genuine and spurious: demystifying adaptation processes in relation to climate change. Environ Soc: Adv Res 1(1):132–155

Tompkins EL, Few R, Brown K (2008) Scenario-based stakeholder engagement: incorporating stakeholders preferences into coastal planning for climate change. J Environ Manage 88(4):1580–1592

Wetherald RT, Stouffer RJ, Dixon KW (2001) Committed warming and its implications for climate change. Geophys Res Lett 28(8):1535–1538

Williams JE, Haak AL, Neville HM, Colyer WT (2009) Potential consequences of climate change to persistence of cutthroat trout populations. N Am J Fish Manage 29(3):533–548

Wise R, Fazey I, Stafford Smith M, Park SE, Eakin HC, Archer van Garderen ERM, Campbell B (2014) Reconceptualising adaptation to climate change as part of pathways of change and response. Glob Environ Change. doi:10.1016/j.gloenvcha.2013.12.002

Wyborn C, Bixler PR (2013) Collaboration and nested environmental governance: scale dependency, scale framing and cross-scale interactions in collaborative conservation. J Environ Manage 123:58–67

Yohe G, Tol RSJ (2002) Indicators for social and economic coping capacity: moving toward a working definition of adaptive capacity. Glob Environ Change 12(1):25–40

Yung L, Patterson ME, Freimund WA (2010) Rural community views on the role of local and extra-local interests in public lands governance. Soc Nat Resour 23(12):1170–1186