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Policy, practice, and partnerships for climate change adaptation on US national forests

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Abstract Climate change presents a challenge to land management agencies tasked with managing landscapes to protect natural resources and provide key goods and services in the face of ecological change, complexity, and uncertainty. Land management agencies, like the U.S. Forest Service, have developed multi-faceted strategies that utilize concepts like resilience and ecological integrity to guide adaptation. To address an extant research need, we conducted a qualitative case study, consisting of interviews with Forest Service staff in the Rocky Mountain Region, to explore how local federal land managers approach adaptation. Our goals were to understand what impacts managers are finding salient, perceptions of current agency strategies, and aspects of policy and practice that support effective adaptation planning. Interview participants anticipate impacts to disturbance regimes, wildlife species, and human uses. Participants intend to draw on agency policies, like its climate change scorecard and its land management planning regulations. However, the participants note that ambiguous concepts, uncertainty, and institutional variables make adaptation planning challenging in practice. A major theme apparent in the interviews was the use of partnerships with a range of other entities to address climate change. Ambiguity associated with concepts like resilience and ecological integrity allow them to function as boundary concepts; however, this ambiguity makes it challenging for managers to operationalize these concepts. These findings revealed that climate change adaptation is leading to and revealing the need for broader governance change. Moving forward, it will be crucial to adjust current governance structures to support long-term partnerships adept at translating scientific knowledge into actions and implementing complex boundary concepts.

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1 Introduction

Climate change affects ecological processes on US forestlands, including wildfires, insect and disease outbreaks, and the distribution of plant and animal species (Vose et al. 2012). While impacts are certain to occur, the specific timing and location of these impacts are uncertain. This creates a challenging dynamic for land management planning. The U.S. Forest Service has developed a climate change strategy that seeks to adapt land management planning and activities to changing conditions, develop scientific information, form partnerships, and educate agency staff and stakeholders (U.S. Forest Service 2008; U.S. Forest Service 2011a). Adaptation planning requires managers to partner with scientists to understand how the changing climate and associated uncertainty influence on-the-ground management actions. It also requires communication with stakeholders to understand which climate change impacts are salient and how the agency can respond through land management actions. As part of this effort, planners and managers must operationalize complex concepts, such as resilience and ecological integrity, that guide the Forest Service's climate change adaptation efforts (Millar et al. 2007; Wurtzebach and Schultz 2016). The literature to date has looked at perceptions of barriers to climate change adaptation in US land management agencies in the USA (Archie et al. 2012; Laatsch and Ma 2015). An important area for further research is understanding how broader adaptation strategies and concepts get implemented in practice. Therefore, we investigated climate change adaptation planning efforts within a region of the U.S. Forest Service to understand which issues are most salient to decision-makers, the utility of current agency strategies in guiding climate change adaptation planning, and how aspects of forest governance are affecting and evolving in response to adaptation efforts.

1.1 Knowledge management and governance institutions in climate change adaptation

Adaptation planning processes benefit from scientific knowledge that reflects the decision-making context (Dilling and Lemos 2011). Optimizing the salience, credibility, and legitimacy of knowledge supports effective use of science in decision-making (Cash et al. 2003; Kirchhoff et al. 2013). Credibility describes the "scientific adequacy of the technical evidence and arguments" (Cash et al. 2003). Legitimacy describes whether stakeholders view information as "respectful of [their] divergent values and beliefs" (Cash et al. 2003). Salience captures "the relevance of the assessment to the needs of decision makers" (Cash et al. 2003). At a broader scale, the salience of the impacts of climate change contributes to the proclivity of decision-makers to pursue adaptation actions (Pralle 2009; Dannevig and Hovelsrud 2016). Thus, understanding local decision-making requires the identification of salient impacts of climate change.

Perceptions of the credibility, salience, and legitimacy of information may differ between scientists and managers and individuals within these groups (Lemos et al. 2012). Boundary organizations that enable frequent and iterative interactions between these groups help to bridge the apparent gap between science and decision-making and help to build adaptation capacity (Cash et al. 2003; Dilling and Lemos 2011; Graham and Mitchell 2016). For example, science-management partnerships draw on research scientists' technical expertise and managers' local knowledge to develop vulnerability assessments that address climate change vulnerabilities of specific resources for individual national forests (Littell et al. 2012; Raymond et al. 2013) and for regions of the National Forest System (Halofsky et al. 2017).

Effective boundary work often focuses on boundary objects, which are "adaptable to different viewpoints and robust enough to maintain identity across them" (Star and Griesemer 1989). Furthermore, tools that support implementing adaptation actions are key outputs of boundary work (Graham and Mitchell 2016).

Governance factors shape boundary work and the production of knowledge (Ascher et al. 2010; Wellstead et al. 2013). Governance variables include statutory and administrative laws, the agency's climate change strategies and internal policies, and informal institutional factors that shape resource management, such as interactions with stakeholders (Moser and Ekstrom 2010; Wellstead et al. 2013; Chaffin et al. 2014). Governance barriers to climate change adaptation can include ambiguous agency policies, limited resources, and the political acceptability of decisions (Jantarasami et al. 2010; Moser and Ekstrom 2010; Archie et al. 2012; Lemieux et al. 2014; Kemp et al. 2015). Organizational change to overcome these barriers may occur through cyclical processes that resemble adaptive management; these processes incorporate efforts to understand the system, its characteristics, and its challenges, followed by the implementation of strategies that can include policy change or are designed to influence other aspects of agency culture, practice, and decision-making institutions (Burch 2010; Moser and Ekstrom 2010; Berkhout 2012). Communication through boundary organizations and with stakeholders helps support organizational change (Vogel et al. 2007; Moser and Ekstrom 2010; Wilby and Vaughan 2011). Informal and formal leadership plays a key role in setting adaptation goals, developing plans, and evaluating success (Burch 2010; Moser and Ekstrom 2010; Wilby and Vaughan 2011; Berkhout 2012). The Forest Service has a history of evolving as an organization to approach challenges and embrace new paradigms (Kennedy and Quigley 1998). Thus, the agency affords an opportunity to understand the dynamics of governance change as land managers embrace climate change adaptation.

1.2 Climate change adaptation through resilience

The concept of resilience plays a central role to adaptation efforts by the Forest Service (Millar et al. 2007; Laatsch and Ma 2015). Managing for resilience predicates on an understanding of system dynamics that recognizes uncertainty, interactions at different scales, and non-linear dynamics (Walker et al. 2004). Resilience generally refers to the ability of ecosystems to recover from and absorb disturbances (Holling 1973). In Forest Service documents, the agency frequently uses resilience in the sense of ecological resilience; it sometimes describes social-ecological resilience but to date has rarely worked this type of resilience into planning and management activities (Bone et al. 2016). Criticisms of resilience suggest that the concept has become increasingly vague; accordingly, operationalizing resilience in specific management concepts is difficult (Brand and Jax 2007; Walker et al. 2012). Implementing resilience benefits from efforts to "specify which system configuration and which disturbances are of interest" (Carpenter et al. 2001). Resilience functions as a boundary concept for managers and scientists pursuing adaptation and multiple groups can generally coalesce around it while still allowing room for differences of interpretation; however, to be a useful organizing concept for management, it would have to be perceived as legitimate by relevant stakeholders (Star and Griesemer 1989; Cosens

et al. 2014). While considerable debate about the utility of resilience has occurred, the concept has gained traction in US land management contexts (National Park Service 2010; Bone et al. 2016). Accordingly, understanding the concept and its interpretation in this institutional setting remains an important research need.

1.3 Climate change policies in the U.S. Forest Service

Under the National Forest Management Act of 1976 (NFMA), national forests must develop land management plans (i.e., "forest plans") that set the context for land management activities over a period of 10 to 15 years. In 2012, the Forest Service promulgated revised regulations under the NFMA, collectively known as the "2012 planning rule." This rule requires forests to consider climate change as a system driver when developing plans that address sustainability, multiple use, timber, and plant and animal diversity requirements (36 C.F.R. §219.8-§219.11). With regards to sustainability, plans should restore and maintain ecological integrity (36 C.F.R. §219.8), a concept that is related to resilience and is defined in regulations as "the quality or condition of an ecosystem when its dominant ecological characteristics occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence" (36 C.F.R. §219.19). The agency also has several national-level policies that spur forests to incorporate climate change in day-to-day operations (Laatsch and Ma 2015). The agency developed the Performance Scorecard for Implementing the Forest Service Strategy Climate Change Strategy (hereinafter, "Scorecard") to assess the performance of individual national forests in responding to climate change across ten different items in four categories: agency capacity, partnerships and education, adaptation, and mitigation and sustainable operations (U.S. Forest Service 2011b).

Understanding how the agency is evolving its management approaches to address climate change requires consideration of knowledge sources that inform decision-making, governance factors that influence decision-making, and the interpretation of complex concepts such as resilience. This research offers a view into the Forest Service's efforts to address climate change by addressing the following questions:

1) What impacts of climate change are currently salient to decision-makers in the Rocky Mountain Region?
2) To what extent are local managers employing current agency strategies, such as the Scorecard and the 2012 planning rule, to approach climate change?
3) How are aspects of forest governance affecting and evolving in response to local adaptation efforts?

2 Data and methods

This article reports on a qualitative case study focused on the U.S. Forest Service's Rocky Mountain Region, which includes national forests and national grasslands located in Colorado, Wyoming, Kansas, Nebraska, and South Dakota. This region is heavily used for recreational activities and supports snowpack that is the source of water for agricultural, domestic, and municipal users. We selected this setting for these reasons and because our location in this region helped us access participants and understand local concerns. This research approach is appropriate given the focus on a relatively new area of investigation: contemporary efforts to

address climate change by a land management agency in a particular setting (Yin 2014). We conducted interviews with 18 Forest Service staff members. These staff members included primarily national forest level staff, such as forest planners, climate change coordinators, and resource staff; we also interviewed regional staff. We used purposive sampling to identify interview participants based on their involvement in and knowledge of climate change planning activities (Yin 2016). We concluded our interviews upon reaching saturation on key issues (Creswell 2014). Interview participants engaged in adaptation through their responsibilities in developing land management plans, project plans, and complying with Scorecard requirements. Each interview lasted approximately 1 h and followed a semi-structured format; we used a series of standard questions but pursued relevant lines of questioning not directly included in the interview protocol. We conducted the interviews in accordance with a protocol approved by our institution's Institutional Review Board. The interviews were recorded and transcribed. We used the NVivo qualitative data analysis software package to conduct data analysis (version 11, QSR International). We coded these transcripts in order to identify both predefined themes aligned with our research questions (e.g., salient impacts) and also emergent themes (e.g., conceptual ambiguity) (Corbin and Strauss 2008; Creswell 2014). We also combined codes in higher-order categories (Yin 2016). We report on our findings and themes and provide illustrative quotes in our results to give examples of data excerpts.

3 Results

3.1 Salient impacts of climate change

Salient impacts of climate change included impacts to disturbance regimes, wildlife, and human uses. Many participants expressed concern that climate change would exacerbate disturbances, although they expressed uncertainty about whether impacts could be attributed directly to climate change. For instance, they noted that climate change might increase wildfire intensity, frequency, and severity. However, participants viewed the present as a fact-finding stage and said that they would prioritize monitoring for trends in changes to fires rather than plan specific actions to respond to expected impacts of climate change to wildfire regimes. Participants also noted that climate change might exacerbate insects and diseases, recalling the significant impacts of the mountain pine beetle (*Dendroctonus ponderosae*) in the early 2000s and recent spruce beetle (*Dendroctonus rufipennis*) outbreaks. However, the participants were cautious to make explicit connections between these insect outbreaks and climate change. One participant noted: "It's not entirely easy to get scientists to say: 'That's because of climate change.'" Participants said this lack of a conclusive scientific understanding of the connection between disturbances and climate change hampers efforts to communicate about these issues with the public. Nonetheless, one participant noted that, given the high visibility of the impacts of insect outbreaks, the public is especially interested in this topic. Several participants also noted concerns about impacts on wildlife species. One participant noted that cutthroat trout (*Oncorhynchus clarki virginalis*) and Canada lynx (*Lynx canadensis*) "drive a lot of our high [elevation] habitat management," a trend that will continue in light of these species' vulnerabilities to climate change.

Participants also noted the potential for direct impacts to human uses. Participants discussed recreational activities as important uses in the region. One participant noted that, while impacts to ski areas due to declining snowpack may occur, they are less likely to be significant in

Colorado, since the state's ski areas are generally located at high elevations. Interview participants expressed concerns that climate change may impact the delivery of water to off-forest users. Many national forests in the region contain headwaters for streams and rivers that provide municipal and agricultural water to downstream users. As one participant put it, "Everything around climate change in this region goes back to water usage tied to agriculture." While the Forest Service does not directly manage the water infrastructure, interviewees discussed the possible future need for expansions to existing reservoirs and development of higher elevation reservoirs as responses to variability in precipitation associated with climate change.

3.2 Attitudes towards existing agency strategies

Participants noted that the 2012 planning rule requires consideration of climate change, and, consequently, they intended to incorporate climate change considerations into upcoming planning efforts. However, familiarity with the planning rule and its requirements appeared to vary according to whether forests were scheduled to revise plans in the near future. Interviewees also cited the Scorecard as a key component of the agency's response to climate change. Many of the interviewees served as their unit's climate change coordinator, responsible for filling out the Scorecard on an annual basis. One participant noted that the Scorecard was helpful in raising awareness of the multiple dimensions of the agency's response to climate change. However, participants were generally critical of the Scorecard. Participants found that the responsibility of completing the Scorecard often came on top of other job responsibilities and was not a priority. The interviews suggested that the Scorecard does not motivate substantive action to address climate change, particularly in the context of adaptation. Participants described the Scorecard as a "massive nuisance," "an afterthought and…a box checker." One participant explained: "If that person also has other responsibilities…the amount of time and seriousness they put into it just isn't there." According to several, better direction from leadership about what the Scorecard should accomplish and how to carry out specific objectives would be beneficial.

Interview participants identified the concepts of ecological integrity and resilience as pillars of the agency response to climate change adaptation. Forest Service interviewees felt obligated to incorporate these concepts in planning efforts due to regulatory requirements and agency expectations; however, they had trouble operationalizing these concepts, especially when interacting with the public. For example, two interviewees referred to resilience as a "buzzword." Others suggested that using resilience as the "main driver" for management offers flexibility and allows the Forest Service to "pick the path of least resistance and sort of get as many birds as [it] can with one stone." Another interviewee expressed that promoting resilience to climate change may be interpreted by the public as "greenwashing" of projects that involve commercial logging. Interview participants anticipated similar challenges associated with implementing the concept of ecological integrity. This term was also cited as a "buzzword" and as interpreted as "greenwashing" by the public. Nonetheless, one interviewee found it helpful, saying, "I have been beating the drum that it's about ecological integrity, but everybody has their perspective of what that means." The interviewee suggested that, despite managers generally understanding what the concept means on-the-ground, it is difficult to work it into planning documents and guide management actions based on ecological integrity. Central to ecological integrity is the idea of ecological characteristics falling within natural

range of variation, another concept that interviewees said results in ambiguity especially when presenting the concept to the public.

In general, interviewees discussed challenges associated with interpreting the policies that they are required to implement, given the uncertainty and complexity associated with climate change. These challenges included uncertainty about future climatic conditions as well as uncertainty with important concepts. One interviewee said, "We're planning for climate change but what does that actually mean?" Another interviewee suggested that uncertainty about climate change impacts and risks associated with management actions make decision-making significantly more "impactful," meaning that this interviewee perceived greater consequences of management decisions given the added challenge of climate change.

3.3 Other aspects of governance affecting climate change adaptation

A major theme that emerged from interviews was the use of partnerships with a range of other entities, including Forest Service scientific researchers, academic researchers, other federal agencies, state and local governments, and non-governmental organizations to address climate change. These partnerships, interviewees said, increase the detail and extent of information about climate change available to the Forest Service and help address barriers associated with limited capacity.

Several interviewees emphasized an integral role for the Forest Service's research branch in informing on-the-ground management actions and consideration of climate change through the convening of workshops and provisioning of scientific synthesis reports. Forest Service staff also develops and manages several nationwide datasets deemed useful by interviewees, such as the Forest Inventory and Analysis National Program (FIA), which provides data on shifts in vegetation species and carbon stocks. Staff also was looking to outside scientists and partners. As one interviewee put it, Colorado's Front Range is "a pretty data rich environment with two major universities, federal research…[and other] organizations and institutions." Collaborating with the "science community and academia," according to interviewees, allows national forests to prioritize monitoring to address the "most key" items looking forward and to grapple with uncertainty. According to several interviewees, working with other agencies offers an additional opportunity to address data needs in support of climate change considerations. Interviewees noted that the Forest Service collaborates with other agencies through the National Interagency Fire Center to produce useful data pertaining to wildfire season duration and frequency, the collaborative NorWeST database for data on stream temperatures, and the Natural Resources Conservation Service's SNOTEL dataset to track snowpack and precipitation.

Interviewees also used partnerships with environmental advocacy groups and other non-governmental organizations to respond to climate change. One interviewee pointed out that The Nature Conservancy led a recent initiative to develop vulnerability assessments addressing ecosystems, wildlife species, and social sectors. According to participants, environmental groups were more likely to comment on climate change than the general public and sometimes have significant research capacity, which may benefit forests in planning and monitoring efforts. One participant noted that their forest had started dialogue with its advocacy partners early in its planning process to develop a shared understanding of how their forest plan would address complicated topics like climate change adaptation. The participant noted that this communication required telling partners: "When the rubber hits the road and we put this plan

out, we don't want to put out a plan that we can't achieve; that sets us up for failure, so we need all you guys to think about how we're going to do something."

Participants noted barriers associated with governance. Several participants identified declining budgets and workforces as a challenge in addressing climate change and other aspects of forest management; borrowing from management to fund wildfire suppression further cuts into budgets, participants said. While partnerships offer an opportunity, participants were still concerned about limited scientific information and local expertise hindering the implementation of climate change policies. Several participants anticipate needing to coordinate adaptation activities with water providers, which operate permitted reservoirs and water diversion structures on Forest Service land. One interviewee also noted the fact that forest supervisors often feel pressure from "local politicians and local stakeholders" to suppress wildland fires, and thus are limited in their ability to make the decision to let wildfires burn despite the potential benefits to ecosystem function and resilience. In essence, interviewees explained that political pressure might interfere with managing for climate change.

4 Discussion

These interviews demonstrate that Forest Service staff members in the Rocky Mountain Region understand the salience of and challenge inherent in planning and managing for climate change. Challenges span a range of relatively disparate elements, including responding to disturbances, ensuring the continued delivery of important services, developing partnerships, considering complex scientific information, grappling with uncertainty, and maintaining public accountability. We reflect here on key findings from our research and then focus on two key themes that warrant additional discussion: how to adjust institutional design to support climate change planning and grappling with uncertainty and ambiguous boundary concepts.

4.1 Key findings on salience and the utility of early approaches to climate change planning

A key contribution of this project is to understand what climate change impacts are currently salient to forest managers in the Rocky Mountain Region. Interview participants identified salient impacts primarily to resources of social, economic, or ecological importance. An important question, then, is how should knowledge of salient impacts inform management? Scientists may shape their assessments around these impacts, and managers may use these impacts as a useful entry point to discuss climate change adaptation with the public. However, focusing on salient impacts may obfuscate other potential climate change impacts that are not currently salient but could be in the future (Adger et al. 2009). Furthermore, interview participants noted that scientists cannot always clearly outline connections between climate change and witnessed events, such as insect outbreaks, thus suggesting a need to bolster the scientific credibility of certain impacts of climate change (Cash et al. 2003; Berkhout 2012). These observations have implications for science-management partnerships. Managers need help figuring out how to communicate about salient issues with the public while appropriately characterizing the relationship to climate change and its uncertainty. Scientists can help managers to understand what impacts may become more salient in the future, and to translate salient impacts into adaptation actions and strategies (Graham and Mitchell 2016).

We also assessed early approaches to promoting adaptation planning within the Forest Service, particularly the Scorecard and 2012 planning rule. These approaches have raised awareness of the various dimensions of the agency's strategy to climate change among interview participants; however, institutional characteristics are limiting their utility. For example, participants suggested that they are currently only able to cursorily implement the Scorecard's requirements, due to time and capacity limitations, and limited buy-in from its users. At the time of this research, the agency was in the process of developing a second generation of the Scorecard in order to enhance its utility. However, it appears that institutional changes, including how people's time is allocated, leadership, and culture may be necessary to promote the organizational change necessary to embrace climate change adaptation planning (Moynihan and Landuyt 2009; Moser and Ekstrom 2010).

4.2 Institutional change to support climate change adaptation planning

The relatively new responsibilities associated with planning for climate change reflect a broader shift in environmental governance paradigms; climate change adaptation necessitates more responsive and adaptive approaches to decision-making and carves out a new role for scientific knowledge in informing management. However, efforts to address climate change must occur within the structure of existing governance arrangements, working with decades-old policies, navigating potentially antagonistic relationships with stakeholder groups and political pressures, and grappling with the constant challenges of limited resources for strategic planning efforts. A major question for environmental governance scholars is how to adapt existing governance arrangements to tackle new challenges, like adaptation planning.

Already, some changes are occurring in national forest governance, based on our interviews. Many participants mentioned relying on partnerships with public stakeholders and researchers to address climate change. Partnerships allow managers and scientists to work together to coproduce knowledge pertaining to complex concepts, such as resilience and ecological integrity, that is useable in specific contexts (Archie et al. 2012; Lemos et al. 2012; Wurtzebach and Schultz 2016). Scientists draw on their technical expertise to translate information and make it accessible to managers (Cash et al. 2003). Additionally, managers must communicate to scientists how local conditions, institutional requirements, and political realities confine management actions (Littell et al. 2012; Wellstead et al. 2013; Blades et al. 2016). Land management agencies may benefit from incorporating stakeholders and public preferences in science-management partnerships to improve perceptions of legitimacy and identify key ecosystem services in need of adaptation (Ascher et al. 2010; Dilling et al. 2015; Golladay et al. 2016). Scaling up existing partnerships, promoting new partnerships, and improving networks of partnerships would likely benefit the Forest Service and other organizations managing for an uncertain future (Chaffin et al. 2014; Dilling et al. 2015).

Effective boundary work involves iterative and multi-directional communication (Cash et al. 2003; Dilling and Lemos 2011). The Forest Service could use its hierarchical organizational structure and temporally staggered forest planning processes to share exemplar approaches to climate change adaptation in forest plans and vulnerability assessments in support of a larger shift in governance and management suitable to address climate change. Updating information technology, such as a web databases, may support the distribution of this information (Moser and Ekstrom 2010; Heikkila and Gerlak 2013). The agency also may need to reorganize so there is adequate capacity to gather lessons learned. For this and the broader suite of agency strategies to address climate change, leadership will be critical, as

interviewees noted. In order to promote successful organizational change, leaders must communicate the rationale for changes and help staff understand their importance and utility, and provide strategies and tools, thus affecting both structural and cultural aspects of the organization, which work together to support organizational learning and change (Fernandez and Rainey 2006; Moynihan and Landuyt 2009; Moser and Ekstrom 2010). For example, leaders pursuing institutional changes to support adaptation planning should identify opportunities to overcome preferences for traditional approaches to land management (Jantarasami et al. 2010). In summary, updating and developing new policies, partnerships, and organizational structures will be important to supporting climate change adaptation efforts; it also will be critical for the agency to consider how informal institutions, including communication and decision-making norms, influence adaptation efforts, and how to update these as is necessary.

4.3 The challenge of operationalizing boundary concepts

Most interviewees discussed challenges associated with operationalizing boundary concepts such as resilience and ecological integrity, which are central concepts in climate change adaptation for the Forest Service and other agencies (Wurtzebach and Schultz 2016). The concept of ecological integrity plays a "foundational" role in forest planning, as one interviewee put it, yet the concept means different things in different contexts. The planning rule describes ecological integrity in terms of two dimensions: natural range of variation and resilience (36 C.F.R. §219.19). Resilience is exceedingly challenging to operationalize, particularly in terms of climate change, given its impact on a range of stressors (Bone et al. 2016). Several interviewees viewed resilience as a buzzword that is difficult to communicate to the public who are wary of the concept as a means of "greenwashing" traditional management paradigms. However, eliminating resilience, ecological integrity, and climate change from the management lexicon is not an option, given current policy guidance and observed changes in the environment.

These are the benefits and challenges of boundary objects or concepts (Star and Griesemer 1989; Cohen 2012). Our research reveals a clear and present tension faced by land management agencies embracing such concepts. They are useful in that multiple communities embrace them, and they are broad enough to serve as an agency-wide policy goal, working across a wide variety of social and ecological contexts (Star and Griesemer 1989). At the same time, their ambiguity and the differences among the communities that embrace them make it difficult and controversial for managers to operationalize them in practice (Brand and Jax 2007). Operationalizing boundary concepts requires expertise and deliberation with partners, including both science-providers and stakeholders, and often is a process that reveals the different ways various groups interpret and apply these concepts. For these reasons, the agency will need to provide the leadership, capacity, and incentives to engage in these activities if it is to successfully utilize complex boundary concepts as guiding mandates. This will be particularly important during land management planning endeavors.

There are several innovative approaches to adaptation that offer promise. There exist, for example, structured approaches to understanding and operationalizing resilience that engage scientists, managers, and public stakeholders in a learning process (see e.g., Resilience Alliance 2010). The Adaptive Silviculture for Climate Change project is using robust experimental design and long-term monitoring to implement resistance, resilience, and transition management approaches and assess how they fare over time (Nagel et al. 2017). Place-based collaborative efforts offer opportunities to explore the dynamics of addressing climate change

through science-management-public partnerships (Golladay et al. 2016; Halofsky et al. 2016). For instance, interview participants noted that the two Collaborative Forest Landscape Restoration Program (CFLRP) projects operating in the region are grappling with many of these issues (see Schultz et al. 2012). The Forest Service's Intermountain and Northern Region Adaptation Partnerships are also working at regional scales to develop vulnerability assessments that inform adaptation on national forests (Halofsky et al. 2017). These innovations reflect principles of successful organizational adaptation, including iterative processes, new approaches to scale, and collaboration with stakeholders (Moser and Ekstrom 2010; Dilling and Lemos 2011; Wilby and Vaughan 2011; Berkhout 2012).

5 Conclusions

Climate change presents an acute challenge to land management activities in the United States and elsewhere. This research demonstrates the utility of understanding how local-scale, administrative staff have begun to acknowledge the challenge and implement current policies. These staff have begun to note salient impacts of climate change to disturbances, wildlife, and human uses. While agency policies pertaining to climate change have raised awareness of the issue, their utility has been limited. The study highlights some of the broader governance challenges inherent to climate change adaptation planning. While this study is limited as a single case study, it reveals potential governance challenges and solutions that are likely applicable across a variety of land management contexts and would benefit from further research. These interviews suggest a need to better understand how scientific knowledge and concepts can be translated to support management actions. The broader question is how to adjust current governance institutions, including key aspects of organizational structure and behavior, to support partnerships and the implementation of complex boundary concepts to support adaptation planning. Given the vast diversity of ecologies, geographies, and societies, every land management context is inherently different. However, we posit that there may be common governance changes that are needed to tackle the present challenge of adapting to climate change.

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