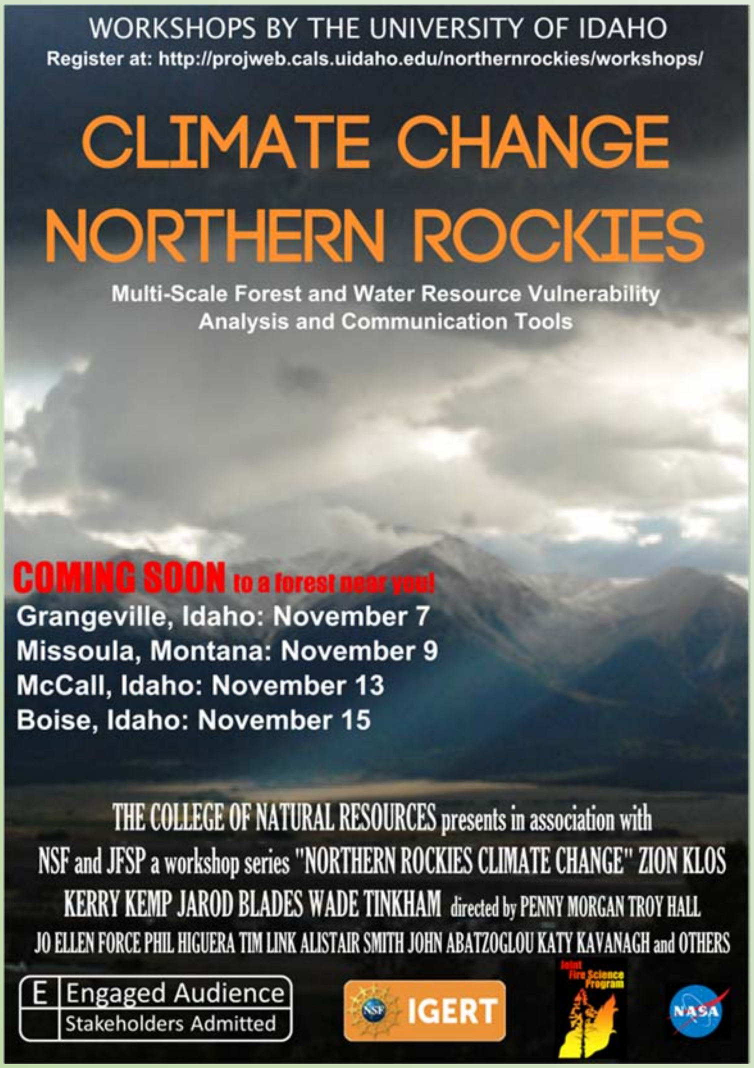

Project Title: Exploring How Deliberation on Scientific Information Shapes Stakeholder Perceptions of Forest Management and Climate Change

Final Report: JFSP Project Number 11-3-1-33

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For further information go to www.firescience.gov

* The cover image is the advertising poster that was used for the workshops of this project.

I. Abstract

Climate change has resulted in rapid biophysical changes in forests of the western U.S. and has prompted the need for an increased understanding of potential impacts and adaption measures. Land managers, policy makers, and community officials lack locally relevant climate change science and are urgently calling for research to inform management decisions. Nevertheless, a substantial disconnect remains between emerging scientific information and its application in management decisions. Effective action depends on understanding regional and local implications of climate change and open, reasoned discussions about current research and potential mitigation actions among researchers, land managers, and other stakeholders. Boundary objects have been shown to be useful frameworks for facilitating the transfer of knowledge between researchers and natural resource managers. Our research aimed to convey locally relevant information on shifts in forest ecosystems and fire regimes due to changing climate, and assess how participation in deliberative workshops influenced forest managers' opinions, intention, and use of climate change science.

We focused on the development and exchange of current climate change research across scientific-agency-policy boundaries. A goal of our research was to enhance the understanding of the cognitive processes by which boundary objects may operate. We conducted four climate change workshops in the U.S. northern Rocky Mountains and applied multiple methods of inquiry (pre-post interviews and questionnaires) to understand whether the workshops and climate change science were perceived as useful, credible, and if they influenced behavioral intention.

Major Findings:

- Climate Change Workshops were effective for the rapid delivery of complex wildland fire science in a setting that capitalized on the use of visualization and interactive participation.
- Perceptions of the usefulness and credibility of climate change science significantly increased, and were found to be significant predictors of behavioral intention to use climate change science in land management decisions.
- Our application of multiple inquiry methods revealed the importance of scale, model complexity, uncertainty, and visualization for designing, implementing, and evaluating climate change boundary objects.
- Participants considered simple and direct measures of climate (i.e., precipitation, temperature, and snowpack) to be more credible, useful, and more likely to be used in management decisions than models that were more complex with higher levels of uncertainty (e.g., vegetation and fire modeling).

II. Background and Purpose

Climate change represents one of the greatest challenges to land management and society. It is expected to alter the mountainous ecosystems of the U.S. northern Rocky Mountains and affect the people who depend on them for ecosystem services and livelihoods. The U.S. Forest Service (USFS) will not fulfill its mission to promote sustainability without integrating climate change impacts into management plans and actions (U.S. Department of Agriculture Forest Service, 2008). With rapid biophysical changes already occurring in these forests, the USFS and other stakeholders are increasingly seeking to understand and mitigate the effects of a changing climate on public lands. Effective action depends on understanding regional and local implications of climate science and open and reasoned discussions about current research and potential mitigation actions among researchers, land managers, and other stakeholders (Dietz, 2013; Hall, Wilson, & Newmann, 2012; Luskin, Fishkin, & Jowell, 2002; Parkins & Mitchell, 2005).

In the fall of 2012, our interdisciplinary research team of biophysical and social scientists conducted a series of climate change workshops (CCWs) focused on conveying locally relevant information on shifts in forest ecosystems due to changing climate. The CCWs facilitated the exchange of current climate change knowledge across research and management boundaries in the U.S. northern Rocky Mountains. Our CCWs were designed to bring abstract concepts of climate impacts to regional and local scales through the synthesis of historical empirical data and the visualization of future forest and water modeling.

To assess how participants' beliefs about climate change science credibility, salience, legitimacy, and behavioral intention changed from before to after the CCWs, we applied a rigorous pre-test/post-test, mixed methods approach. Drawing upon multiple frameworks, we evaluated the effectiveness of the boundary objects and organization. We contribute to both theory and practice of boundary objects and organizations by carefully attending to each of the factors posited as leading to more effective outcomes. Additionally, we incorporated ideas from social learning theory to develop activities likely to enhance collective understanding in the application of science to practice, including visualization techniques.

Background of Boundary Organization and Boundary Object Theory

The process by which research communities establish relationships with the worlds of land management and policy is commonly referred to as boundary work (Clark et al., 2010; Gieryn, 1983). Boundaries are symbolic distinctions that categorize objects, people, practices, and even time and space (Lamont & Molnár, 2002). Many boundaries reflect unique ways of understanding and approaching management between different social sectors and disciplines. Boundaries have been addressed in two ways: though the concept of boundary objects and as boundary organizations.

Boundary organization theory offers one approach to understanding and enhancing interactions between specific groups or organizations that lie on the boundary between worlds. Boundary organizations -- institutions or settings that facilitate knowledge and information exchange among scientists, decision-makers, and land managers -- can facilitate a multi-directional flow of information between science and management at multiple scales (Cash & Moser, 2000). The primary assumptions of boundary organizations set forth by Guston (2001) are: 1) they exist at the frontier of the science and management communities but are accountable to both; 2) they involve participation by land managers/policymakers and researchers, as well as professionals who mediate between them; and 3) they provide opportunities for the co-production of boundary objects, which are "objects that live in multiple social worlds and which has different identities in each" (Star & Griesemer, 1989, p. 409). In the context of climate change, research specific to boundary organizations and objects is relatively new.

Guston (2001) and Miller (2001) identified the importance of creating incentives for the production of boundary objects, involving key participant institutions (scientific and management communities), and maintaining lines of accountability to both scientists and managers. In a separate line of work (but related to boundary organization theory), boundary object theory originated with Star and Griesemer's (1989) study of a museum classification system as a boundary object. Research on boundary objects describes them as hybrid, flexible, and portable tools that help people from multiple sectors negotiate knowledge transfer between the science, management, and policy realms (Cutts, White, & Kinzig, 2011; White et al., 2010). Boundary objects link different sets of diverse interests, and they can be physical or virtual entities that promote cohesive working relationships. Therefore, boundary objects can be constructed differently depending on the work or informational needs of different social groups or worlds that are creating, using, and modifying them.

Boundary objects include decision support systems, scenarios, and GIS technology (e.g., Girod, Wiek, Mieg, & Hulme, 2009; Harvey & Chrisman, 1998; White et al., 2010). Model-based decision support tools have become popular as boundary objects that connect natural resource sciences and decision-makers, because models can provide a common means for visualizing complex information (White et al., 2010). Transforming abstract numeric and verbal data into imagery can greatly reduce the risk of confusion while honoring the inherent human preference for visual information (Al-Kodmany, 2002). We defined our boundary organization as the CCW as a whole, and the boundary objects were the climate change modeling tools used during the CCW.

Despite the interest in and promise of boundary organizations and objects, the different types, natures, and effects of boundary objects in natural resource management are poorly understood (White, 2011). Their flexibility and lack of common classification have prompted efforts to create standardized sets of constructs to define and measure boundary objects (Cutts et al., 2011; White et al., 2010). Cash et al. (2003) identified three elements integral to linking knowledge and action for environmental decision-making: credibility, salience, and legitimacy. Credibility involves the scientific adequacy of the technical evidence and arguments. This has been qualitatively assessed in terms of perceived scientific accuracy, validity, technical evidence, data quality, calculations, and visual display (White et al., 2010). Salience (or usefulness) is the perception of whether the boundary object has the ability to meet the needs of decision-makers. Legitimacy reflects the perceptions that the production of information and technology has been respectful of the divergent values and beliefs of stakeholders, unbiased in its conduct, and fair in its treatment of views and interest. In our study, these constructs were evaluated in terms of both the CCW organization and individual boundary objects. We also desired to explore how institutional factors influence the likelihood of using climate change science in land management decisions.

Institutional environments affect the capacity of using climate change science in land management. Agency policies, directives, diverse priorities, time, funding, politics, litigation, and the perception of limited discretion in decision making are a few potential organizational barriers that may supplant the previously described variables related to boundary objects and organizations (Archie, Dilling, Milford, & Pampel, 2012; Jantarasami, Lawler, & Thomas, 2010; Wright, 2010). Organizational factors are likely have a direct causal impact on behavior. The more barriers a person perceives is anticipated to result in a lower likelihood of intending to use climate change research in land management.

Our rigorous pre- and post-workshop interviews and questionnaires were designed to evaluate the effect of the boundary organization and objects, and explore the hypothesized relationships between the factors that predict likelihood to use climate science in forest management. The specific hypotheses we tested were:

H1: Perceptions of (a) the usefulness and (b) the credibility of climate change science will significantly increase as a result of participating in the CCWs.
H2: Higher perceived credibility will be associated with higher perceived usefulness of climate change science in management decisions.
H3: Higher perceived usefulness will be associated with higher intention to use climate change science in future work.
H4: Higher perceived organizational barriers will be associated with (a) lower perceived usefulness of and (b) lower intention to use climate change science in management decisions.

H5: Participation in the CCW will result in a positive overall evaluation of the credibility, salience, and legitimacy of the boundary organization.

The methods section will begin with a description of how our CCWs and climate change modeling tools were designed to meet the theoretical assumptions and best practices of boundary organizations and objects, followed by a description of the mixed-methods study design, measurements, and analysis framework.

III. Methods

Workshops as Boundary Organizations

The overall CCW represented a boundary organization existing at the frontier between the science and management communities and involved participation by actors from both communities (Guston, 2001). Our CCWs met the assumptions of boundary organizations because: 1) the workshops were conducted with USFS personnel (including decision-makers), university researchers, and regional collaborative group members; and 2) the tools used in the CCW were developed and used by professionals from both the scientific and land management worlds. The visualization and modeling tools used during the CCWs represented boundary objects and were designed to facilitate the exchange of climate change research (Figure 1).

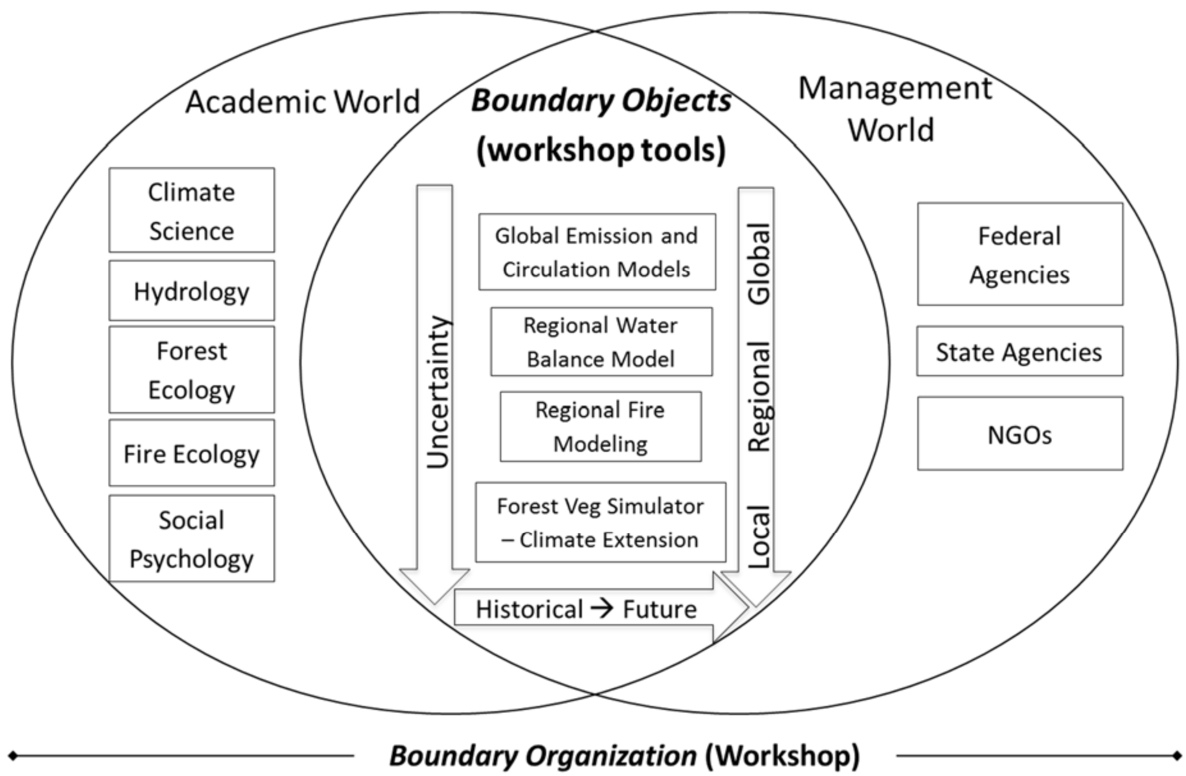

Figure 1. Conceptual diagram of the climate change workshops (CCWs), boundary organization, that linked research and management worlds. The boxes on the left, academic world, are the disciplines represented by our interdisciplinary research team. The boxes on the right in the management world

represent the diversity of stakeholders present at the CCWs. The boxes in the center represent the CCW tools that were evaluated as boundary objects. The large arrows show that the boundary objects spanned global, regional, and local spatial scales, historical and future temporal scales, and that uncertainty was present at all scales and compounds when transitioning from global to local and historical to future.

Although there has been limited documentation of specific variables, structures, and processes of boundary organizations (Parker & Crona, 2012), the management culture (inter-personal relationships between participants and boundary organizations) has been identified as a key consideration (Crona & Parker, 2011). This was an important concern for our CCWs, where the university research team made many efforts to establish and nurture relationships with potential participants. Careful planning helped to ensure that the design, organization, and convening of the CCWs served both our purpose and the needs of our participants (Heierbacher, 2010; McCoy & Scully, 2002).

Recognizing human limitations related to information processing, cognitive load, numeracy, and attention span, we took careful consideration regarding how we designed and presented climate change information during the workshops (Figure 2). We capitalized on the importance of visualizing climate change trends and impacts to summarize a large amount of complex information and make the information locally relevant (e.g., Al-Kodmany, 2002; Lipkus, 2007; O'Neill & Nicholson-Cole, 2009; Sheppard, 2005). Because humans possess a limited capacity to receive and use complex information (Lang, 2000; Sylwester & Cho, 1992/3), we prioritized visualizations that were simple (listed below), but that would hold attention and promote careful consideration. Visualization is an important part of the boundary object for conveying uncertainty in complex information in a way that participants could process (MacEachren, Robinson, & Hopper, 2005).

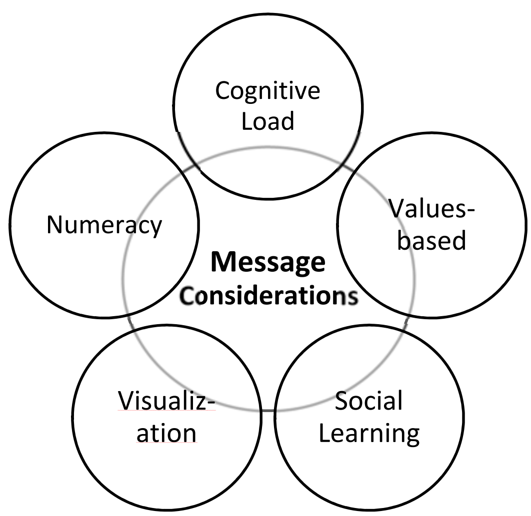

Figure 2. Climate change message considerations for the workshops.

The CCW tools represented and satisfied the assumptions of boundary objects because each tool can be freely used by different actors in different locations, they model and predict future scenarios, they explain the meaning and significance of climate change effects in forests of the northern Rocky Mountains, and they provide a foundation for climate change discussions among people from different disciplines and sectors. The boundary objects went through integration and coproduction between our research team (the scientific community) and managers (USFS and forest collaborative groups). The final boundary objects represented diverse information, compiled at different scales:

1. Global Scale: An overview of global climate, historically (in both a geologic and contemporary context) and future projections, including a review of the greenhouse effect and historical C02 concentrations. For future projections, we provided an introduction to global circulation models (GMCs) and emission scenarios and discussed the relative uncertainty of each. This section provided the global and atmospheric considerations necessary to understand the practical workings and limitations of the input data needed for the models described below.

2. Regional-Scale Water Resources: Historical data provided examples of how temperature, precipitation, snowpack, streamflow, and stream temperature have changed within the region over the past century (Klos et al., 2014). Future projections showed how these systems may continue to change (UW-CIG, 2012). A regional hydroclimatic model was used to create 3D visualizations of potential changes in snowpack accumulation and flood risk in the regional and local landscapes surrounding the CCW locations. Additionally, river-scale streamflow models provided insight about potential regional and local changes in timing and amount of in-stream water availability (UW-CIG, 2012).

3. Regional-Scale Forest and Fire Ecology: Regional vegetation models were used to project future tree species and biome distributions of the northern Rocky Mountains based on climate envelope modeling (Rehfeldt, Crookston, Warwell, & Evans, 2006; Rehfeldt, Ferguson, & Crookston, 2008). Climatic fire models were used to visualize projected increases in area burned in the western U.S. (Littell, 2011), increasing fire season length, and days with high fire danger ratings. These models demonstrated how climate shifts in precipitation and temperature could link to forest vegetation and wildfire regimes.

4. Local-Scale Vegetation Simulations: The Climate Extension to the Forest Vegetation Simulator (Climate-FVS) (Crookston, Rehfeldt, Dixon, & Weiskittel, 2010) was developed to provide forest managers a tool for considering climate change effects at the forest stand level. Working closely with the model developers and stakeholders from each CCW forest, a combination of forest type, elevations, and time scales was selected for evaluating a series of management regimes under a climate change scenario. The modeling was used to determine when particular tree species would not be able to regenerate due to unsuitable climate. Further, effects of different management regimes (e.g., prescribed fire, mechanical thinning, or a combination) were simulated to evaluate the increase or decrease in resilience of these species throughout time under anticipated climate change.

In addition to the boundary object variables described above, we recognized the need to employ best practices related to active/collaborative learning and small group processes during the CCWs (Bonwell & Eison, 1991; Cohen, 1994; Daniels & Walker, 1996; Michael, 2006). We desired workshop participants to be actively engaged with the opportunity to work together in small groups and articulate their understanding and opinions to others (Rivard & Straw, 2000). Thus, we created opportunities for participants, under semi-structured facilitation, to carefully reflect upon the climate change science, consider how it might be useful in land management, and identify where gaps exist.

According to boundary organization theory, successful exchange of the climate change information during the CCWs was more likely to occur if the workshops and modeling tools were perceived as credible, salient, and legitimate by the participants. These factors provided a framework for evaluating the boundary objects and organizations (legitimacy was not evaluated for the boundary objects used during the CCW because the models were designed specifically for climate, water, vegetation, and fire science disciplines, and therefore were not intended to be applicable to all agency natural resource disciplines). Specifically, we assessed the extent to which our boundary objects and organization, were perceived as credible and salient. Then, through regression analysis, we assessed whether these factors, as well as organizational barriers, predicted participants' intentions to use climate change science in management practice.

Design and Sampling

We employed a mixed sequential equal status design (Leech & Onwuegbuzie, 2009; Onwuegbuzie & Collins, 2007) to triangulate quantitative and qualitative data in the evaluation of our CCW boundary organization and objects. Qualitative interviews provided depth and richness to our understanding of the utility of climate change science in land management, while quantitative surveys permitted us to establish the magnitude of relationships among constructs.

The CCWs were quasi-experiments because the participants were self-selected (i.e., lacked random assignment) and we did not attempt to isolate the effects of the pre-test or use a control group; otherwise they had similar purposes and structural attributes to experiments (Creswell, 2009; Graziano & Raulin, 2009). Our interrupted time series design involved pre-test measures (i.e., interviews and questionnaires), a treatment (i.e., the workshop), and post-test measures (i.e., questionnaires and interview).

We purposefully selected individuals who satisfied multiple criteria (listed below) to maximize our understanding of the effectiveness of our CCWs (Creswell, 2009; Onwuegbuzie & Collins, 2007; Teddlie & Yu, 2007). Using a snowball sampling approach, we asked participants to recommend other participants, including both climate change accepters and deniers (Creswell, 2009). The sample frame involved selecting U.S. National Forests that were: 1) located within the northern Rocky Mountains (Idaho and Montana); 2) contained a steep elevation gradient with a diversity of forest types; 3) were identified as being sensitive to substantial temperature and precipitation changes (Klos, Link, & Abatzoglou, in revision); and 4) had local and regional forest collaborative groups of citizens who were engaged with USFS activities.

For each CCW location, participants were selected from three strata: forest managers/ decision makers and planners (e.g., fire management officers, district rangers, interdisciplinary team leaders, National Environmental Policy Act document editors), forest ecologists (e.g., silviculturists, foresters, fire ecologists), and water resource specialists (e.g., hydrologists, fisheries biologists, riparian ecologists). These strata represented the main natural resource and climate change topics presented during the CCWs (forest, fire, and water resources) and included individuals who regularly work with land management documents that incorporate climate change science. A target of 25 participants at each CCW location (100 total) was chosen to detect a moderate (Cohen, 1988), one-tailed relationship between our constructs of interest with 0.80 power at the 5% level of significance (Onwuegbuzie & Leech, 2004). Though by quantitative survey standards this is a relatively small sample for correlational or comparative designs (Bartlett, Kotrlik, & Higgins, 2001), small samples are appropriate for exploratory research and mixed method quasi-experiments (Onwuegbuzie & Collins, 2007; Onwuegbuzie & Leech, 2004).

To reach theoretical saturation through our interviews we followed the recommendations of Onwuegbuzie and Collins (2007) to include at least three participants per subgroup in a quasi-experimental mixed methods design. Guest, Bunce, and Johnson (2006) found that the majority of themes reach saturation with the completion of 12 interviews. Therefore, because this study involved CCWs in four locations with three disciplinary strata, we conservatively aimed to conduct pre- and post-workshop interviews with 12 people at each location, and 16 in each disciplinary stratum (48 total pre-post interviews).

Interview and Survey Content

The telephone interviews and online questionnaires both addressed the variables discussed in the introduction, but the interviews were less structured, allowing for probing and elaboration (Morse & Richards, 2002). Each participant was generally asked the same questions in the same order, with some variation in probing questions based on initial responses. Pre-workshop questions pertained to the primary focus of the study, following the theoretical model of Figure 3, such as "how useful is climate change science in the work you do?" Probing questions related to these included, "what about that particular research makes it useful or impedes is usefulness?" Post-workshop interview questions asked participants to evaluate how their thinking changed regarding the credibility and salience of climate change science in their work based on the boundary objects presented at the CCWs. We also asked participants to evaluate the overall credibility, salience, and legitimacy of the CCWs.

For the self-administered written questionnaires, participants had the option of taking the pre-workshop survey either online prior to the actual CCW date, or on site prior to the start of the CCW. All CCW participants were encouraged to complete a written or online survey at the conclusion of each CCW. To ensure maximum participation, we followed a modified version of Dillman's Total Design Method that included an initial email notifying participants that they would receive a request to complete an online survey, an email with a survey link (the electronic survey was deployed using Qualtrics), a follow-up reminder email, and personal phone calls to those who had not completed the survey (Dillman, Smyth, & Christian, 2009). Refer to Appendices H - P for all participant correspondence materials, the survey instrument, and interview instrument.

The pre-workshop questionnaire had nine sets of questions. Most questions had 5- or 7-point Likert-type response options. The first section asked questions about the salience (i.e., usefulness) and credibility of climate change science that were adapted from previous boundary object work (Cutts et al., 2011; Jacobs, Garfin, & Buizer, 2009; White et al., 2010). Questions were also asked about potential barriers to addressing climate change in their work (Wright, 2010). A final section asked participants about their disciplinary expertise, years worked in the northern Rocky Mountains, highest level of education obtained, gender, and political orientation.

The post-workshop questionnaire had six sets of questions, including the questions from the pre-workshop questionnaire pertaining to the usefulness and credibility of climate change science. An additional section asked participants to evaluate the credibility, salience, and legitimacy of the entire CCW (Buizer, Jacobs, & Cash, 2010; Cash, 2001; Crona & Parker, 2011; Guston, 2001; Miller, 2001; Parker & Crona, 2012).

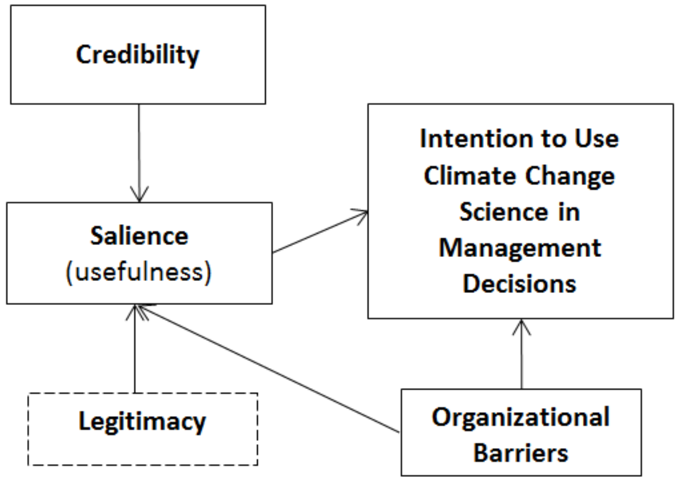

Figure 3. Integrated model of boundary variables, organizational barriers, and the intention to use climate change research in land management decisions. The dotted line indicates that legitimacy was only measured for the CCW boundary organization (not the boundary objects).

Interview and Survey Data Analysis

All interviews were digitally recorded with permission and transcribed verbatim. Analysis of the interview data followed a team-based strategy to developing a codebook guide (Boeije, 2002; MacQueen, McLellan, Kay, & Milstein, 2002; Ryan & Bernard, 2003). An initial list of parent nodes included categories of anticipated themes based on our theoretical framework and interview protocol. After the parent codes were defined, the research team reviewed the codebook and discussed any discrepancies in code interpretations. Using the team-developed parent nodes, two team members coded each interview. The process continued until each coding category had a definition, an example, and rules for application. The acceptable level of reliability was set at Cohen's kappa > .80 (Krippendorff, 2004), which was achieved after four rounds of coding. After reliability was established, one coder applied codes to all the interview text and codes were attached to text in NVivo (Appendix P).

Our team also established rapport with the participants through prolonged engagement, such as multiple phone conversations, so that they felt comfortable to provide honest and candid answers. A research journal was kept by all members of the research team during the interview process to track responses and events, allowing us to identify any outside events that could have affected interpretation of a participant's interview (Shenton, 2004).

Survey responses were analyzed using the Statistical Package for the Social Sciences (SPSS, 2010) to reduce multi-item measures to indices using factor analysis (direct oblimin rotation) with a Cronbach's alpha reliability coefficient cutoff level of 0.70 or greater (Field, 2005; Kline, 2011). Paired sample T-tests were used to determine whether variables of interest changed from pre- to post-test, and one-way analysis of variance was used to determine whether the variables of interest varied by discipline or location. Ordinary least squares (OLS) regressions were used to test the relationships presented in Figure 3 (Barker et al., 1994; Graziano & Raulin, 2007). We used Baron and Kenny's (1986) process for testing the mediating effect of salience/usefulness on the relationships of credibility and organizational barriers to behavioral intention.

IV. Key Findings

A total of 97 people participated in the four CCWs; however, for this paper we only analyzed responses from 61 participants who completed all of the pre-test and post-test quantitative measures (61= Missoula: 19, Grangeville: 15, Boise: 16, and McCall: 11). We also collected 60 pre-workshop interviews and 35 post-workshop interviews. Substantially fewer post-workshop interviews were collected because severe winter conditions and conflicting agency training prevented the attendance of 25 people that had been pre-interviewed. Analysis revealed few differences related to participants' specific discipline and workshop location (see Appendix S for supplemental data tables specific to discipline and location). Therefore, the findings presented here combine all four CCW locations and disciplines into one sample. Quantitative findings are presented in conjunction with selected qualitative interview excerpts to provide richness and context.

Credibility of Climate Change Boundary Objects

Participants found global and regional climate change science to be significantly more credible than local (forest stand-level) climate change science both before (t_{52}= 6.9, p< .01) and after (t_{57}= 6.8, p< .01) participating the CCWs. Interestingly, the credibility of both historical data (t_{55}= 3.9, p< .01) and projected/modeled data (t_{55}= 4.3, p< .01) increased to a similar degree as a result of the CCWs. Many participants commented that the historical data we presented made them more aware that climate change is currently affecting forests they manage, not just something that will happen in the future. One manager remarked how the CCW made her aware that climate change modeling that illustrates impacts "certainly needs to play a bigger role…because the time frames are a lot quicker than I was thinking going into the workshop. Yes, we certainly need to start using that in all of our decision making processes" (Manager 4, Boise).

The interview data reflected the important role of scale in determining whether participants felt the boundary objects were credible. Participants often said that the climate change science needed to be used for management at the scale that the data represented, and that often mismatches occur. Discussions about the local-scale modeling, both before and after the CCWs, often described an overall lack of confidence in modeling predictions at smaller, project-level scales. For example, one water resources specialist noted before the CCWs that "one of the biggest problems I have with [models is the] validity…it is so out of whack…no way you can say that's going to happen on that acre of ground, on that thirty-meter pixel." He then further described his frustration with the use of models after the CCW by saying, "the data that you used at that broad level, you can't take that same data and take it down right to [a local] scale" (Water/Physical 1, McCall). Though skepticism about the credibility of local-scale modeling was commonly observed before and after the CCWs, participants did indicate that these types of models were helpful for exploring different management actions and illustrating climate change impact trends at regional scales – illustrating that sometimes a negative relationship existed between credibility and usefulness. That is, participants may have thought the credibility of local-scale vegetation modeling was low, but that they were still useful for exploring management alternatives.

Further, many participants shared after the CCWs that they were more "convinced of the water [science], the hydrologic side of it that was presented, and less [convinced] on the terrestrial side" (Water/Physical 10, Missoula), suggesting that the water resources modeling was perceived to be more credible than the vegetation modeling. This was further explained by a forest manager in terms of the landscape and model complexity inherent in vegetation simulation modeling. He reflected that “the regional [hydrologic modeling] was the most helpful because getting down to the forest level [vegetation modeling] is more microclimate driven… it’s harder to transition down to the smaller vegetative scale” (Water/Physical 7, Grangeville). Model complexity and spatial scale were clearly influencing perceptions of boundary object credibility.

A Grangeville participant described how “there’s a lot of skepticism and skeptics [about climate change science]…that’s what I perceive as the biggest challenge both internally and externally…there’s a lot of perspectives” (Vegetation/Fire5, Grangeville). However, after participating in the CCW, the same participant reflected that “I could see where [the CCW tools] could be incorporated. It relates to that best available science factor.” This suggests that the participant felt that the CCW influenced her perceptions of the credibility of the climate change science presented and classified it as “best available science,” which is a requirement for all federal and state land management documents. In other words, some participant attitudes improved about the defensibility and credibility of climate change science, even in the presence of internal and external skeptics.

Salience/Usefulness of Climate Change Boundary Objects

Before the CCWs, participants recognized the utility of climate change science for the work they do, especially for long-term land use planning (Table 1). However, many participants attended our CCWs because they wanted a better understanding of the local- and regional-scale context of climate change science including tools that they could consistently use agency-wide. Participation in the CCW increased ratings for four of the five “usefulness” survey questions. Additionally, salience/usefulness items on the post-test all had mean values >1.0, suggesting that the boundary objects were perceived as useful (Table 1).

Interviews indicated that participation in the CCW and exposure to boundary objects helped participants see how climate change science could be applied to land management decisions. For example, before the CCW, one participant noted that he had “yet to see a user friendly tool that is easily accessible,” but after the CCW, he reflected that “being able to look at the models and kind of see the trend” was “really useful” (Water/Physical 8,). The information was something he could share with his crew and “get them thinking in the direction we are going.”

In the post-test survey, participants were asked to evaluate the usefulness of different spatial scales of climate change science presented at the workshops. Overall, the regional-scale water (m= 2.2), vegetation, and wildland fire research (m= 2.2) was considered to be significantly more useful than global-scale (m= 1.4, t_{61}= 8.5, p< .01) and local-scale (m= 1.9, t_{61}= 4.1, p< .01) climate change science (Table 1).

Interviews shed light on why participants viewed climate change science as more useful at regional scales, and more difficult to use at smaller project-level scales where the landscape is varied and uncertainty in the models increases. For example, a forest ecologist summarized his view that “every time you step down [in scale] you have to carry the uncertainty from the level above and how that compounds” (Vegetation/Fire 9, Missoula). After the CCWs, many participants observed that climate change science is more salient for landscape-scale planning efforts, specifically describing the usefulness of the qualitative nature of the science for establishing “desired conditions in our forest plans”

(Vegetation/Fire3, Missoula). Not surprisingly, the usefulness of climate change science was inherently connected to participant perceptions of climate change science credibility.

Table 1. Pre-test, post-test, and change of overall usefulness, credibility, organizational barriers, and behavioral intention

Const-ruct	Items*	N	Pre test	SE	Post test	SE	Mean Change	SE	Paired T-test (*p*)
Credibility	Global and regional climate change science is credible.	60	2.0	0.1	2.1	0.1	0.2	0.1	0.13
	Local (forest stand-level) climate change science is credible.	52	0.9	0.2	1.2	0.2	0.3	0.2	0.11
	Historical data and calculations used in climate change science are credible.	56	1.5	0.2	2.1	0.1	0.6	0.2	**0.00**
	Projected/modeled future data and calculations used in climate change science are credible.	56	1.0	0.2	1.6	0.1	0.6	0.1	**0.00**
	I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	55	1.1	0.2	1.5	0.1	0.4	0.2	**0.03**
	FACTOR - Credibility	61	1.2	0.1	1.7	0.1	0.5	0.1	**<0.01**
Usefulness PRE-POST	Climate change science is useful in my work.	61	2.0	0.1	2.1	0.1	0.1	0.1	0.33
	Climate change science is useful in long-term land use planning.	58	2.3	0.1	2.4	0.1	0.2	0.1	0.16
	Climate change science is useful for specific management projects.	60	1.5	0.2	1.7	0.1	0.3	0.1	**0.04**
	FACTOR – Usefulness in general for planning	60	1.9	0.1	2.1	0.1	0.2	0.1	**0.05**
	Models that simulate future vegetation scenarios are useful in land management.	58	1.6	0.1	1.5	0.1	-0.1	0.2	0.51
	Models that simulate future precipitation patterns are useful in land management.	59	1.5	0.2	1.7	0.1	0.2	0.2	0.29
	FACTOR – Usefulness of models that are resource specific	59	1.6	0.1	1.6	0.1	0.0	0.1	0.99
Usefulness POST Only	The global climate change information is useful for land management (modeling and emission scenario information).	60			1.4	0.1			
	The regional climate and water research is useful for land management.	61			2.2	0.1			
	The regional vegetation and fire research is useful for land management.	59			2.2	0.1			
	The local-scale forest vegetation and climate simulations are useful for land management.	58			1.9	0.1			
Org Barriers	Funding is a constraint for addressing climate change in my work.	60	1.2	0.2					
	Time is a constraint for addressing climate change in my work.	59	1.5	0.2					
	The politics of climate change are a constraint for using the science in my work.	59	0.5	0.2					
	FACTOR – Organizational Barriers	61	1.1	0.2					
Behavioral Intention	I plan to use climate change science in future work that I do.	61	2.0	0.1	1.9	0.1	-0.1	0.1	0.56
	I plan to use *global* climate change science in future work that I do.	58			1.1	0.2			
	I plan to use the *regional climate and precipitation* research in future work that I do.	61			2.0	0.1			
	I plan to use the *regional vegetation and fire* research in future work that I do.	58			1.7	0.1			
	I plan to use the *local-scale forest vegetation and climate simulations* in future work that I do.	55			1.4	0.1			

*Scale values were -3 strongly disagree to 3 strongly agree

Organizational Barriers to Using Climate Change

Participants agreed that using climate change science in land management was consistent with their organizations' mission and within their job descriptions. However, the interviews revealed that, until recently, climate change has not been considered a high-priority topic when compared to other natural resource issues, such as special status species, wildland fire, or noxious weeds. Organizational factors were clearly a factor for using climate change science in management decisions. Workshop participants generally agreed that the organizational barriers of time, funding, and politics are a constraint for using climate change science in their work (Table 1). One participant noted that "so many times here [at] the district level you're caught in the deadlines or time frames and [to] get [a] project put out at [a] particular time, you don't have the time to build in all the literature and to track [climate change research], that is if you have any other kind of life (laughing)" (Water/Physical 9, Grangeville). The same participant then went on to describe how the CCW helped address barriers of time, because "having somebody…collecting the information is very useful… You realize there are things out there that will be quite helpful"; she further reflected that the CCW "gave me somewhere to go for the information that I need to back, scientifically back, what I am saying in my documents."

Intention to Use Climate Change Boundary Objects

Prior to the workshops, participants agreed that they plan to use climate change science in future work, and that opinion did not significantly change as a result of participating in the CCWs. However, after the CCW, participants reported that they were significantly more likely to use the regional climate change boundary objects related to water (m= 2.0), vegetation, and fire (m= 1.7) than the global models (m= 1.1, t_{72}= 7.4, p< .01) and local-scale vegetation simulations (m= 1.4, t_{70}= 5.0, p< .01). This was reflected during many of the interviews; for example, one water resources specialist noted before the CCW that he has seen it used "on broad scale but not on smaller scale, not on project level stuff." After the CCW he described how higher-level agency direction may influence the use of climate change science: "there is a lot of talk on how you could use [Climate-FVS], and there's a lot of interest that, I think we just don't have a real good handle on how to use it as an agency, except on a very broad regional scale" (Water/Physical5, McCall). This was consistent with our findings related to the usefulness of climate change science – that it is more useful, and more likely to be used, at regional scales.

Model Testing for Boundary Objects

Data Reduction – Factor Analysis

The exploratory factor analysis (EFA) conducted for the five usefulness items revealed two dimensions with good reliability in both the pre-test and post-test (Table 2): 1) general usefulness of climate change science for planning, and 2) the usefulness of models that simulate future vegetation and precipitation. Using indices computed as the mean of items loading cleanly on each factor, participant perceptions of the usefulness of climate change science for planning significantly increased as a result of participating in the CCWs (t_{60}= 1.9, p= 0.05), but perceptions of the usefulness of models did not increase (Table 1).

The EFA conducted for the five credibility items revealed single reliable dimensions in both the pre-test and post-test (Table 3), so the mean of the items was computed. Perceptions of credibility significantly increased because of participating in the CCWs (t_{60}= 4.01, p< 0.01). The EFA conducted for the three organizational barriers items revealed a single dimension with high reliability (Table 4), so a single factor was computed. Table 5 displays the bivariate correlations among the computed indices. The strongest correlates of behavioral intention to use climate change science, for both the pre-test and post-test, were usefulness and credibility. The strongest correlates of usefulness, for both the pre-test and post-test, were credibility and organizational barriers.

Table 2. Summary of exploratory factor analysis results for the **usefulness** of climate change science.

	Factor Loadings (pattern matrix)			
	PRE-TEST		POST-TEST	
Item	Usefulness in General n=58	Usefulness of Models n=59	Usefulness in General n=60	Usefulness of Models n=56
Climate change science is useful in my work.	**0.81**	-0.01	**0.97**	-0.22
Climate change science is useful in long-term land use planning.	**0.81**	0.16	**0.82**	0.20
Climate change science is useful for specific management projects.	**0.93**	-0.10	**0.74**	0.24
Models that simulate future vegetation scenarios are useful in land management.	-0.03	**0.97**	0.14	**0.82**
Models that simulate future precipitation patterns are useful in land management.	0.04	**0.94**	-0.07	**0.93**
Factor means (scale -3 to 3)	1.89*	1.58	2.07*	1.58
SE	0.12	0.14	0.10	0.11
Cronbach's alpha	0.82	0.91	0.82	0.76
Eigenvalue	2.76	1.30	2.89	1.11
% Variance explained	55.23	26.07	57.88	22.10

*Significant increase from pre-test to post-test at the p<.05 level

Table 3. Summary of exploratory factor analysis results for the **credibility** of climate change science.

	Factor Loadings (pattern matrix)	
Item	PRE-TEST n=50	POST-TEST n=54
Global and regional climate change science is credible.	0.81	0.74
Local (forest stand-level) climate change science is credible.	0.77	0.61
Historical data and calculations used in climate change science are credible.	0.82	0.67
Projected/modeled future data and calculations used in climate change science are credible.	0.87	0.77
I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	0.89	0.71
Factor means (scale -3 to 3)	1.24*	1.70*
SE	0.13	0.09
Cronbach's alpha	0.89	0.70
Eigenvalue	3.46	2.45
% Variance explained	69.26	49.02

*Significant increase from pre-test to post-test at the p<.05 level

Table 4. Summary of exploratory factor analysis results for **organizational barriers** that could be a constraint for addressing climate change.

Item	Factor Loadings (pattern matrix) PRE-TEST n=57
Funding is a constraint for addressing climate change in my work.	0.87
Time is a constraint for addressing climate change in my work.	0.88
The politics of climate change are a constraint for using the science in my work.	0.73
Factor means (scale -3 to 3)	1.07
SE	0.17
Cronbach's alpha	0.76
Eigenvalue	2.07
% Variance explained	69.01

Table 5. Correlation matrix (Pearson's *r*) for the pre-test (below the diagonal) and post-test (above the diagonal) factors used in the multiple regressions.

	Factors	1.	2.	3.	4.	5.	Mean	SE
1.	Behavioral Intention	**1.00**	.81**	.35**	.55**	.35**	1.63	0.12
2.	Usefulness	.79**	**1.00**	.38**	.61**	.54**	2.07	0.09
3.	Usefulness of Models	.38**	.31**	**1.00**	.38**	0.11	1.58	0.11
4.	Credibility	.55**	.47**	.55**	**1.00**	0.22	1.69	0.09
5.	Organizational Barriers	.48**	.49**	.29*	0.24	**1.00**	1.07	0.17
	Mean	1.98	1.89	1.58	1.24	1.07		
	SE	0.13	0.12	0.14	0.13	0.17		

*Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level
Note: The pre-test value for organizational barriers was used for correlations during both the pre-test and post-test (it was only measured during the pre-test).

Regression Analysis of Usefulness and Behavioral Intention

We used ordinary least squares linear regressions to explore relationships between the independent variables (perceived credibility and organizational barriers) and the dependent variables of salience/usefulness and behavioral intention at both time periods (see Figure 3). Baron and Kenny's (1986) approach to determining mediation was followed, using five sequential regression models (Table 6). Credibility and organizational barriers were significant predictors of perceived usefulness during both the pre-test and post-test (Model 1). Next, we independently regressed intention to use climate change science on usefulness (Model 2), credibility (Model 3), and organizational barriers (Model 4). Each of these yielded a significant positive relationship, with usefulness for planning explaining nearly two-thirds, and credibility explaining one-third, of the variance in intention. Surprisingly, the positive relationship between organizational barriers and intention was the opposite of the negative relationship we had hypothesized.

Lastly, we ran a multiple regression that examined the relationship of all of the predictor variables on behavioral intention (Model 5). Usefulness for planning and credibility remained significant predictors of intention for the pre-test, and usefulness for planning was the only significant predictor of intention for the post-test. The direct effect of credibility on intention weakened in the final pre-test model and disappeared in the post-test model after adding the mediator usefulness. The direct effect of organizational barriers on intention was independently a significant predictor of usefulness (Model 4), but that effect also disappeared in the final models with the addition of the usefulness mediator. These findings suggest that the effect of credibility and organizational barriers on behavioral intention is largely mediated by perceived usefulness.

Table 6. Linear regression results for usefulness of climate change science (pre-test and post-test).

	Pre-test				Post-test			
	β	*t*	*Adj. R^2*	*F*	*β*	*t*	*Adj. R^2*	*F*
DV: Usefulness (in general)								
Model 1:			0.32	10.27**			0.54	24.44**
Usefulness of Models	-0.01	-0.08			0.16	1.65		
Credibility	0.38	2.96**			0.46	4.74**		
Organizational Barriers	0.39	3.43**			0.42	4.63**		
DV: Behavioral Intention								
Model 2:			0.63	101.10**			0.65	114.04**
Usefulness	0.80	10.10**			0.81	10.70**		
Model 3:			0.29	25.64**			0.29	25.81**
Credibility	0.55	5.06**			0.55	5.08**		
Model 4:			0.22	17.86**			0.11	8.11**
Organizational Barriers	0.48	4.23**			0.35	2.85**		
Model 5:			0.66	29.18**			0.65	28.88**
Usefulness	0.63	6.60**			0.82	7.11**		
Credibility	0.21	2.11*			0.06	0.63		
Organizational Barriers	0.12	1.33			-0.11	-1.20		
Usefulness of Models	0.04	0.42			0.03	0.35		

* Significant at the $p < .05$ level, ** Significant at the $p < .01$ level. $\alpha = .05$

Evaluation of the CCW Boundary Organization

Participants were asked during the post-test to rate their level of agreement with 19 statements related to the usefulness, credibility, and legitimacy of the CCWs as a whole (i.e., boundary organization – these are different than the measures of usefulness and credibility described above for boundary objects) (Table 7). Participants agreed that the CCWs were salient/useful overall. While high scores for the first two items were expected, given our use of models and information dissemination, it was encouraging that participants largely agreed that the CCWs made science more useful for management purposes. Many participants commented on the local saliency of the CCW, pointing out that "[the CCW brought] everyone up to date as far as climate change science goes, especially for the [northern Rocky Mountains] rather than just a global picture. It was more about our area of concern and interest… I wasn't aware of those types of data and projections that in the past…. [the CCW] added more precision" (Manager 1, Missoula).

The CCWs enhanced climate change science credibility by translating complex science and meeting science needs with data from multiple sources, and many participants commented they learned during the CCW. One person said, "there were some specific intricacies that I didn't fully understand. I felt I learned something… [such as] increasing in intensity of spring rainfall... and the visual 3D depiction of rain and snowfall" (Manager 6, Missoula). Nearly all participants commented that allowing participants to process the information in small group discussions was a valuable part of their CCW experience. One participant said, "we had a good discussion at our table concerning the uncertainty of making projections, as to what species will be where, [and] how to manage a forest in the future. I was able to talk about that with the folks, and maybe even firm up my opinion about how to deal with that" (Hydro 1, McCall). Participants disagreed with the statement that the presentations at the CCWs were too detailed, but it was often expressed that participants desired more time to reflect on the new information being presented.

Legitimacy was defined as the presentation of information and technology in a manner that is respectful of stakeholders' divergent values and beliefs, unbiased in conduct, and fair in its treatment of views and interest. Participants reported the highest level of agreement with the legitimacy questions. They felt comfortable to share openly, that diverse opinions were welcome, and that they were being heard. Participants felt that an important aspect of the CCWs was that they created a space for scientists, agency personnel, and interested stakeholders who otherwise would not have occasion to work together to engage in productive debate. Many participants commented on the two-way exchange of information; for example, one participant appreciated the forum's goal to "both to share information… and engage with people that are using it and get more feedback" (Manager/Planner 2, Missoula). The application of workshop best practices and careful consideration of science communication resulted in a positive evaluation of the CCW experience.

Table 7. Evaluation of the CCWs as a boundary organization

	Items	**Mean** (n=61)	**SE**
Usefulness (Salience)	There was a clear dissemination strategy for workshop information and outcomes.	2.2	1.7
	The workshop encouraged the use of models and tools for linking science and decision making.	2.0	0.8
	The workshop helped to understand how research could be used in decisions being made.	1.8	0.9
	Scientific information and results were translated for practical use.	1.8	1.0
Credibility	Information needs were connected with sources of information.	2.0	0.9
	The small group discussions helped me understanding the presented information.	1.8	1.4
	The workshop added value by combining data and information from multiple sources.	1.8	1.0
	The workshops helped identify the underlying assumptions of the information presented.	1.6	1.1
	The presentations were too detailed – too much information was presented	-1.5	1.2
	There was adequate time to reflect on new information.	1.1	1.4
Legitimacy	Active listening took place during the Q&A and small group sessions.	2.6	0.9
	It was easy for participants to speak openly.	2.3	0.6
	Different opinions were welcome.	2.3	0.6
	I was comfortable talking about any concerns or disagreements.	2.2	0.7
	The workshop created a forum for individuals who otherwise would not have occasion to work together on these topics.	1.9	0.9
	The workshop helped participants engage in productive debate.	1.7	1.1

	The workshop was accountable to both resource specialists and decision-maker needs and interests.	1.6	1.4
	The workshop promoted information exchange between scientists, agency and interested stakeholders.	1.4	1.1
	Diverse disciplines and interests were not represented at the workshop.	-0.7	1.6

Scale values: -3 strongly disagree to 3 strongly agree

V. Management Implications

We evaluated the effectiveness of boundary objects (i.e., workshop components) and a boundary organization (i.e., the overall workshops) for influencing workshop participants' attitudes towards the usefulness of climate change science. We gained a greater understanding of boundary work variables, organizational barriers, and intention to use climate change science for management decisions at various spatial and temporal scales, using multiple methods of inquiry.

The Effectiveness of Boundary Objects

We found support for several of our hypotheses related to the boundary objects. Similar to the case study by Cutts, White, and Kinzing (2011), we found that participant perceptions of the usefulness (H1a) and credibility (H1b) of climate change science significantly increased because of participating in the CCWs. Positive relationships were also observed between credibility and usefulness (H2), and between usefulness and intention to use climate change science in future work (H3). Our data provided rich context about how participation in the CCW influenced (or did not influence) perceptions of salience and credibility at different spatial scales. Prior to the CCWs, many participants indicated that climate change science was most useful for long-term land use planning and regional scale management decisions (e.g., forest plans), rather than fine-scale specific forest projects (e.g., plot-level thinning projects), and the CCW did not have a significant impact on this perception. Participant comfort with using climate change science at regional scales may be due, in part, to current agency guidance for using climate change science at that scale (Dillard, 2008; U.S. Department of Agriculture Forest Service, 2010), suggesting that direction from upper-level management may have influenced participant perceptions of the usefulness and credibility of climate change science during the CCW. However, interviews suggested other reasons about why participants may have favored the regional-scale climate change boundary objects.

Nearly all interviewees indicated a preference for the regional scale hydrologic modeling, where they were able to witness animation of projected changes in the rain/snow transition zones for the forests they manage. This hydrologic modeling was also consistently rated as more useful and credible than global and local-scale modeling on the surveys. The primary difference between the regional hydrologic modeling and the other types of modeling used during the CCW (i.e., regional vegetation shifts, wildland fire area burned, and stand-level vegetation simulations) was that it used direct measures of climate in which projected changes in temperature were used to predict rain versus snow. This was more credible than the vegetation and fire modeling because it relied on a small number of simple variables that were easy to comprehend and had less uncertainty. Credibility decreased with models that were based on factors further away from direct measures of climate, such as those for vegetation and fire, because there were more variables, more complex relationships among variables, and more uncertainty involved. This finding is consistent with other studies which have shown that natural resource managers prefer simple and direct measures of climate (i.e., precipitation, temperature, and snowpack) are the most useful climate for their work (Klos et al., in review).

The visualization and animated aspects of the hydrologic modeling were captivating and powerful. They simplified, summarized, and made the information locally relevant to the CCW participants, consistent with other literature on climate change visualization (e.g., Al-Kodmany, 2002; Lipkus, 2007; O'Neill & Nicholson-Cole, 2009; Sheppard, 2005). The animated sequence allowed participants to focus their attention on climate change impacts within the forests they manage, consider those impacts against other important resources of the region (e.g., big game crucial winter range and Canada lynx habitat), and then process the information in a deliberative small group discussion. The benefits of this approach were consistent with research that has shown that interactivity enhances visualization, notably when used in a carefully designed workshop setting that uses small breakout groups (Schroth, Hayek, Lange, Sheppard, & Schmid, 2011). Similarly, Cutts et al. (2011) highlighted the importance of Geographic Information Systems (GIS), maps, and scientist-guided discussions as being effective boundary objects. This dynamic engagement was not possible with the other types of boundary objects presented at the CCWs, so it is not possible to determine whether the greater credibility of regional hydrologic models was due solely to the visualization or simplicity of the models. Thus, future research should compare the effect of visualizations from models differing in complexity and associated uncertainty to gain a better understanding of effects of visualization on perceptions of credibility and usefulness.

Beyond considerations of visualization and model complexity, there was also clear evidence of a scale mismatch between participant needs related to climate change science and perceptions of the credibility and usefulness of the climate change science we presented. For example, prior to the CCWs, interviewees expressed that climate change science was not useful because it addressed scales that were too broad for forest management, and they desired more local-scale information. After the CCWs, the scale mismatch existed in the opposite direction; although the local-scale climate change science was presented, participants preferred the regional scale modeling. In post-CCW interviews, it was common to hear about challenges related to the uncertainty and assumptions associated with the local-scale vegetation modeling (e.g., the selected types of forest treatments, timing of the treatments, fire disturbances, and reestablishment rate), which people thought reduced the utility for management decisions. Sometimes the local-scale vegetation modeling was credible but not useful because it was accurate for a small parcel of land but did not capture larger landscape variability. Other times the information was described as not credible but still useful; the landscape variability was not captured (lacks credibility) but the model was still considered useful for exploring and comparing land management alternatives. The CCWs revealed a participant preference for boundary objects that provided coarse representations of climate change impacts, such as the hydrologic spatial model that illustrated relative shifts in rain/snow zones, rather than quantitative predictive boundary objects, such as the local-scale vegetation simulations. Many people expressed a desire for local-scale predictive modeling, but said that the complexity and uncertainty was too great to use it as a prescriptive management tool.

These findings related to scale suggest that tradeoffs existed between the usefulness and credibility of climate change modeling at different spatial scales. This is consistent with the findings of White et al. (2010), who found that trade-offs existed between boundary object variables (i.e., credibility sacrificed for increased usefulness) when workshop participants evaluated a complex system dynamics model. The CCWs were effective for helping to define the usefulness of climate change science at different scales and determining which scales were more useful, which is a desirable function of an effective boundary organization (Cash, 2001; Guston, 2001). As climate change science becomes increasingly more accurate and precise over time, future research should track perceptions of its credibility and salience at different spatial and temporal scales.

Organizational Barriers Overcome by Boundary Objects

Although nearly all CCW participants agreed that climate change science should be used in forest management, participants also strongly agreed that time, funding, and politics act as constraints for addressing climate change in their work. The interviews consistently indicated that agency personnel have a full plate of work expectations, and that climate change was yet another responsibility on top of many other higher priority topics. These findings are consistent with other work regarding barriers to using current science in natural resource management (Archie et al., 2012; Jantarasami et al., 2010; Wright, 2010), where a large majority of respondents agreed that time and politics acted as barriers to using the "best available science" in management decisions.

Because of these consistent findings about organizational barriers, we initially hypothesized that higher levels of perceived organizational barriers (time, funding, and politics) would be associated with lower perceived usefulness of climate change science (H4a) and with lower intention to use climate change science in management decisions (H4b). However, neither hypothesis was supported by our findings. In fact, a positive relationship existed between organizational barriers and the usefulness and intention to use climate change science. This finding might be explained by feedback we received from CCW participants throughout the entire research process: no one has the time or ability to collect, interpret, and summarize the vast amount of climate change science available, which is why the CCW was desired as a mechanism to achieve those purposes. The pre-CCW interviews commonly demonstrated this need, and nearly all of the post-CCW interviews commented on how this need was met by the CCWs. This finding was also reflected in the post workshop questionnaire results, where nearly all participants agreed that during the CCW, scientific information and results were translated for practical use. This overcame the barriers of time and funding that would be necessary to gather and synthesize climate change information independently.

Alternatively, if the barriers are related to politics, more credible climate change science may be the solution to political barriers. Regardless, the positive relationship between organizational barriers and intention to use climate change science was perplexing and worthy of further investigation.

A Hybrid Boundary Organization-Object

Prior work has consistently identified the need for boundary organizations to exist as an institution (Cash, 2001; Guston, 2001; White, 2011; White, Corley, & White, 2008), implying some form of long-term relationship between actors from differing worlds of a boundary organization. However, such institutions require high levels of investment and resources from all participants. There is often a need for short-term partnerships that provide rapid science delivery and deliberation between scientists and land managers/decision makers. Thus, we aimed to explore the effectiveness of a hybrid boundary organization-object positioned in the overlapping space of scientific research and natural resource management and decision-making. Further, it is also common to lack the necessary funding that would accommodate a long-term consistent relationship or institution. Thus, we explored how well the CCWs, representing a short-term organization but also a knowledge transfer tool, could achieve the goals and purposes of a long-term institutional organization. Our findings suggest that the CCWs were effective for satisfying the overarching constructs of salience, credibility, and legitimacy, and facilitated a multi-directional flow of information. Participant feedback expressed that the CCWs served the crucial roles of meeting agency desires for linking climate change science with information sources, translating the practical uses of the information, and creating opportunities for deliberation that would otherwise be unlikely between the diverse participants. Participants also agreed that the workshop encouraged the use of models and tools (i.e., boundary objects) for linking science and decision-making, and considered the tools accountable to their needs. These findings are consistent with literature specific to the necessary functions of a boundary organization (Buizer et al., 2010; Cash, 2001; Guston, 2001; Miller, 2001). Participants clearly felt that the CCWs facilitated knowledge and information exchange among scientists, land managers, and decision-makers.

Despite the positive response, there are limitations to conducting a one-day workshop, as opposed to establishing a long-term institution. A central finding of Cash et al. (2003) was that a long-term perspective and commitment to managing boundaries between scientists and decision-makers was more effective for linking knowledge to action. We acknowledge the generally slow impact of ideas on practice, and are curious whether participation in our one-day CCW provided enough time to process the workshop information and link it with day-to-day forest management practices. Participants only slightly agreed that there was adequate time to reflect on new information, but many also stated during the interviews that if the workshop had been longer than one day, participation would not have been possible given time constraints. This finding is not altogether surprising because agency personnel consistently report that time is a major limiting factor for collecting, reflecting on, and using cutting edge science (e.g., Wright, 2010). In order to understand the impact of CCWs on actual forest management practices, future research should focus on the longitudinal effect of short-term workshops designed for rapid science delivery on actual subsequent forest management decisions.

Conclusions

Our intent when designing this study was to address disconnects between the supply of academic research related to climate change impacts and the needs of forest managers for regional- and local-scale information pertinent for decisions. Our findings suggest that the CCWs were effective for the rapid delivery of climate change science in a setting that capitalized on the use of visualization and interactive participation. Perceptions of the usefulness and credibility of climate change science increased, which were found to be significant predictors of behavioral intention to use climate change science in land management decisions.

We designed the CCWs to serve as research-management partnerships aimed at integrating climate change science and management. The CCW participants reflected that, overall, the CCWs were salient, credible, legitimate, and considered to be time well spent and worth the agency investment. The need for ongoing research-management partnerships that synthesize and translate climate change science, such as the CCWs, is imperative in the face of increasing organizational barriers that constrain agency specialists from adequately addressing climate change in natural resource management decisions.

This study represents a unique and rigorous empirical evaluation of boundary objects and hybrid boundary object-organizations. The use of multiple methods of inquiry revealed the primary importance of scale, model complexity, uncertainty, and visualization when designing, implementing, and evaluating climate change boundary objects. Our findings suggest that boundary objects that use direct measures of climate (i.e., temperature and precipitation) at a regional scale are considered more useful and credible than boundary objects that are more complex, use indirect measures, and estimate local-scale climate impacts within ecological systems. Further, the visualization and animated aspects of the boundary objects were important to focus participant attention on climate change impacts within the geographic areas that participants manage.

VI. Relationship to Other Work and Future Work Needed

The relationship of this work to other existing and ongoing research related to climate change communication and deliberation has been integrated throughout the key findings and management implications sections. The obvious future research opportunity related to the CCWs would be to conduct more workshops over time, in the same locations, to evaluate the stability of the measures of boundary objects and organizations in a longitudinal approach. This effort could be expanded to other regions, where the content of the CCWs would be tailored to those specific ecosystems, but the format of the workshops would be maintained (i.e., scale of presentations, small working groups, pre-post measurements). As climate change science becomes increasingly more accurate and precise over time, future research should track perceptions of credibility, salience, and legitimacy of climate change boundary objects at different spatial and temporal scales. To understand the impact of CCWs on actual forest management practices, future research should focus on the longitudinal effect of climate change boundary objects on actual subsequent forest management decisions. Lastly, a major need expressed by land managers was to take our CCW approach to a public audience. The possibilities for exploring climate change communication techniques in a public setting are sizeable, and this could be coupled with the land manager CCWs to understand effective science communication between academics and both of these audiences.

VII. Deliverables

Deliverable Type	Description	Delivery Dates
Conference Talk/poster	Blades, J., Kemp, K., Klos, Z., Hall, T. E. (2013). Integrated Climate Change Workshops with Forest Managers of the U.S. Northern Rockies: Our Experience with the New Paradigm of Interdisciplinary Graduate Education. Digital poster presented at the First Global Conference on Research Integration and Implementation. The Australian National University, Canberra, Australia.	Fall, 2013
	Blades, J., Kemp, K., Klos, Z., Tinkham, W., Hall, T. E., Force, J. E., Morgan, P. (2013). Forest managers response to interdisciplinary climate change science: Understanding the impact of boundary objects' on perceptions of risk and efficacy. Paper presented at the International Symposium on Society and Resource Management (ISSRM), Estes Park, CO and at the America Geophysical Union (AGU) Chapman Conference in Granby, CO.	Fall, 2013
	Kemp, K., Blades, J., Klos, Z., Tinkham, W., Hall, T. E., Force, J. E., Morgan, P. (2013). Climate change in forest management of the northern Rocky Mountains: Implication and barriers for application and management. EPSCoR Climate Change Science for Effective Resource Management Conference.	Summer, 2013
	Blades, J., Klos, Z., & Kemp, K. (2011). *Understanding and communicating the local effects of climate change and social-ecological vulnerability: Enhancing resilience in forests of the U.S. Northern Rockies.* Poster presented at the 2nd Annual Pacific Northwest Climate Science Conference, University of Washington, Seattle, Washington.	Fall, 2011
	Klos, Z., Kemp, K., & Blades, J. (2011). *Understanding and communicating the local effects of climate change and social-ecological vulnerability: Enhancing resilience in forests of the U.S. Northern Rockies*. Paper presented at the CONFOR West – Interdisciplinary Environmental Conference, Canmore, Alberta, Canada.	Fall, 2011
	Kemp, K., Klos, Z., & Blades, J. (2011). *Understanding and communicating the local effects of climate change and social-ecological vulnerability: Enhancing resilience in forests of the U.S. Northern Rockies*. Poster presented at the American Geophysical Union: Fall Meeting, San Francisco, CA.	Fall, 2011

Ph.D. Dissertation	Blades Dissertation Defended at the University of Idaho	November 2013
Refereed Publications	Blades, J., Kemp, K., Klos, Z., Tinkham, W., Hall, T. H., Force, J. E., Morgan, P. (in review). Forest managers' response to interdisciplinary climate change science: Understanding the impact of boundary objects' on perceptions of risk and efficacy. *Studies in Communication Sciences.*	In Review
	Kemp, K., Blades, J., Klos, Z., Tinkham, W., Hall, T. H., Force, J. E., Morgan, P. (in review). Climate change in Forest management of the northern Rocky Mountains: Implication and barriers for application and management. *Ecology and Society.*	In Review
	Blades, J., Hall, T. H. (in prep). Using an expanded risk perception theory to predict credibility, salience, and use of climate change science. *Society and Natural Resources*.	In Prep
Training Materials	Results and training materials provided on project website: http://web.cals.uidaho.edu/northernrockies/workshops/download-workshop-materials/	December 2012 and ongoing

VIII. Literature Cited

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