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Creating Boundary Objects Supports Knowledge Co-development Processes: A Case Study Evaluation from the Colorado Front Range

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Abstract

This qualitative case study evaluates manager and researcher perceptions of the impact of a place-based, collaborative knowledge co-development process and examines the outcomes of that co-development for changes to management approaches. The USDA Forest Service (Forest Service) Rocky Mountain Research Station General Technical Report 373 (GTR-373) is a codeveloped science synthesis that functions as a boundary object providing a framework for planning, designing, and implementing management action for restoration of ponderosa and dry mixed-conifer forests. The process of creating and socializing the GTR-373 framework fostered continual knowledge exchange and engagement between researchers and managers across different organizations and levels of decision-making. This built trust in the information, improved justification for management action, developed a common foundation for cross-boundary implementation, and increased communication. The framework has been applied across jurisdictions and has been used as a foundational tool for training staff and designing projects. However, adapting the GTR-373 framework across scales remains challenging.

Study Implications: This qualitative case study evaluates a co-development process in which researchers and managers from multiple organizations and agencies collaborated to produce a science-informed restoration framework to support forest management on the Colorado Front Range (GTR-373). The process built trust, improved justification for management action, developed a common foundation for implementation, and increased communication. However, cross-boundary management across spatial scales remains challenging, and managers interpret information through organizational mandates and site-specific context. Sustained collaboration between researchers and land managers can help make science actionable and relevant at the appropriate scale for planning and management across expertise and jurisdictional boundaries.

Keywords: collaborative adaptive management, collaboration, knowledge codevelopment, science application, boundary object, forest management

Co-development of scientific knowledge can empower its adoption into forest management practice and strengthen applicability of research questions and approaches. However, few case studies elucidate the specific processes that contribute to successful co-development and application of science. This qualitative case study evaluates manager and researcher perceptions of the impact of a place-based collaborative knowledge co-development process and examines the outcomes of that co-development for changes to management approaches.

Strong relationships between researchers and managers increase salience of research questions, co-ownership of findings, and translation of science principles into practice (Carter et al. 2020; Cook et al. 2013; Cvitanovic et al. 2015; Feldman and Ingram 2009; Fiske and Dupree 2014; Jacobson, Butterill, and Goering 2004; Laurence et al. 2012; Yamamoto 2012). Sustained relationships also support information sharing across expertise and jurisdictional boundaries (Armitage et al. 2011; Raymond et al. 2010). Furthermore, networks that cross such boundaries provide crucial connection points for learning, as knowledge transfer within land management organizations is commonly informal and reliant on relationships and social networks (Archie et al. 2014; Briske et al. 2017; Laatsch and Ma 2016). Boundary-spanning activities and individuals are crucial catalysts for applied knowledge co-development (Bamzai-Dodson et al. 2021; Cross et al. 2022).

In a collaborative context, formalized boundary-spanning activities (e.g., developing charters, shared science, monitoring protocols, etc.) can help focus, document, and formalize ongoing shared knowledge development (Bamzai-Dodson et al. 2021; Beeton, Cheng, and Colavito 2022). Cheng et al. 2015 propose that collaborative groups that co-create and co-manage *boundary objects* increase their sustainability, adaptability, and capacity for action. Boundary objects are co-developed structures or products that address a collective goal or need, and have credibility, salience, and legitimacy

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for multiple organizations and interests (Cash et al. 2003; Star and Griesemer 1989). They are flexible enough to be applied across multiple contexts yet concrete enough to maintain coherence across them (Star and Griesemer 1989). Participatory collaborative processes that encompass multiple viewpoints result in boundary objects that are more legitimate, useable, and better understood (Blades et al. 2016; Star 2010; White et al. 2010). In forest collaborative networks, boundary objects can document shared understanding and knowledge to facilitate cooperative action, synthesize relevant science, and institutionalize science application (Cheng et al. 2015; Esch et al. 2018).

The process of co-producing boundary objects is an important outcome in and of itself and has implications for use of products in practice (Armitage et al. 2011; Beeton, Cheng, and Colavito 2022; Cook et al. 2013; Mattor et al. 2020). We used a social science approach to assess the processes that supported co-development of a science-based boundary object across researcher and practitioner disciplines and examine how the boundary object was incorporated into management action across multiple jurisdictional boundaries.

Case Study Context

This case study of integrating new knowledge into Colorado Front Range forest restoration practice illuminates the collaborative mechanisms that support co-development and adoption of a new boundary object into practice. Our case study relates to the activities leading up to and associated with the co-development process for the *USDA Forest Service Rocky Mountain Research Station General Technical Report 373: Principles and Practices for the Restoration of Ponderosa Pine and Dry Mixed-Conifer Forests of the Colorado Front Range* (Addington et al. 2018; hereafter GTR-373).

As in many fire-adapted forests in the West, extirpation of traditional indigenous land stewardship, as well as legacies of fire suppression and exclusion, logging, grazing, and urban development have affected Colorado Front Range montane forests; they have become more dense, contiguous, and homogenous since Euro-American colonization, more susceptible to insect and disease outbreaks, and are more likely to experience high-severity fire over large extents (Barrett et al. 2021; Battaglia et al. 2018; Kaufmann et al. 2005). In 2002, the Hayman Fire burned at high severity over large areas in this historically frequent-fire system (Fornwalt et al. 2016) and was a turning point for forest managers in Colorado, who realized that past fuel reduction approaches would be inadequate given current and future conditions. As a result, the Hayman Fire kicked off cross-boundary collaboration focused on restoring ecological processes in ponderosa pine and dry mixed-conifer forests, and reducing wildfire risk to communities along the Front Range (Cheng et al. 2015; Front Range Fuels Treatment Partnership Roundtable 2006). When Congress passed the Federal Landscape Restoration Act in 2009 to increase the pace and scale of restoration on National Forest System lands, the Front Range Roundtable (Roundtable) collaborative group was ready to apply for funding through the Collaborative Forest Landscape Restoration Program (CFLRP) and was vitalized and focused by this goal (Cheng et al. 2015). In 2010, funds were awarded through this competitive application process to the Front Range CFLRP (FR-CFLRP) for collaboratively planned projects that used best-available science to design forest restoration treatments and demonstrated commitments to collaborative implementation, monitoring, and adaptive management (Cheng et al. 2015; Schultz, Jedd, and Beam 2012).

As the Roundtable began the work of collaborative implementation, monitoring, and adaptive management of forests, partners were faced with an important question: what should forest restoration look like on Colorado's Front Range? Although knowledge of Front Range fire history and forest ecology existed at the time (Brown and Shepperd 2001; Brown, Kaufmann, and Shepperd 1999; Kaufmann et al. 2005; Schoennagel et al. 2004; Veblen 2003, etc.), the Roundtable identified that they were lacking guidelines relevant to managers working at scales of forest restoration projects (i.e., 100–500 ha) (Cheng et al. 2015, Cheng, Aplet, and Waltz 2019). The effort to coalesce around a common understanding of forest ecology and restoration principles would define the next decade of FR-CFLRP work and nurture many important boundary spanning activities and objects.

GTR-373 synthesizes locally relevant science within an operational framework for forest management on the Front Range and serves as an important boundary object of the Roundtable. GTR-373 was developed by a working group of researchers and forest managers from a diverse range of organizations within the Roundtable, who intended to close gaps between practitioners and researchers to ensure that the completed framework would be applicable to operational forest restoration planning, design, implementation, and monitoring across boundaries. GTR-373 addresses the complex ecological and social landscape of Front Range ponderosa and dry mixed-conifer forests and provides a science-based framework for managers to develop place-based approaches for restoring montane ecosystems to increase future resilience to fire, insect outbreaks, and other disturbances. The framework presents locally relevant ecological information describing how forest structure and composition are shaped by site conditions, history of disturbance, and forest development processes and discusses how to use this information to prioritize and design restoration projects across multiple scales (for additional information about GTR-373 principles, see panel 2, p. 23 of the report). The GTR-373 guidelines generally suggest reducing forest density, enhancing spatial heterogeneity by creating tree groups and forest gaps, and retaining drought- and fire-tolerant species, old trees, and structures for wildlife. This information had not yet been synthesized for the Colorado Front Range as it had been in other historically frequent-fire forests (e.g., North et al. 2009 in the California Sierras; Reynolds et al. 2013 in the Southwest). The GTR-373 framework and the co-development process that led to its publication support a paradigm shift in forest management from thin-from-below approaches towards creating heterogeneity in age classes, structure, and arrangement.

Methods

We used a qualitative approach to conduct semistructured interviews with GTR-373 authors and land managers implementing GTR-373 on the ground; this methodology is appropriate for investigating nuance and is helpful for revealing perceptions of individuals involved in the case study (Creswell and Creswell 2018; Miles et al. 2014). Interviewees were identified in two ways. First, we reached out to a subset of authors listed on the GTR-373 framework to complete pilot interviews. We then used a snowball

sampling technique to develop a network of interview subjects (Creswell and Creswell 2018). During interviews, members of the author team were asked to identify managers who had knowledge about the GTR-373 co-development process and were likely to participate in conversations. In subsequent interviews with managers, participants were also asked to recommend additional interview subjects. Although not all individuals mentioned were interviewed, we selected interview subjects from a variety of agencies and at different levels of decision-making authority. We distinguished interview subjects as GTR-373 authors (authors, $n = 6$) or managers and further specified between those implementing the restoration framework on private, state, and other lands (non-federal managers, $n = 10$, 6 organizations represented) and those implementing on USDA Forest Service lands (Forest Service managers, $n = 11$, 2 national forests represented). Authors who also held manager roles were counted as authors. Forest Service employees were the only federal land managers interviewed; employees from other federal agencies on the Front Range received and participated in some outreach activities, but no authors participated from any federal agency other than the Forest Service, and at the time of interviews, the GTR-373 framework was not being applied broadly on other federal lands. Interviews were conducted in person, over the phone, or via video conferencing from October 2019 to June 2020. Interview questions solicited reflections on the collaborative process and outreach efforts that defined GTR-373 framework development, use and impact of the GTR-373 concepts, and reported change in perceptions and behavior since GTR-373. Some interviews, including all interviews with authors, took place individually ($n = 12$). We also conducted five group interviews where multiple managers from a single agency or organization participated at once to increase efficiency during the COVID-19 pandemic ($n = 15$). In total, twenty-seven individuals were interviewed. Data from group and individual interviews were considered together. Transcriptions and detailed notes from these interviews were coded with qualitative data analysis software Dedoose using a modified grounded theory approach (Charmaz 2006; Gibson and Hartman 2014). This approach allowed us to organize over six hundred unique coded statements and use memos to track themes that emerged as the research developed (Charmaz 2006). The first author conducted all the coding, and the validity of emerging themes was discussed and refined with coauthors and co-interviewers throughout the analysis process. Following interviews, we used member checking approaches to synthesize themes and findings for presentation and discussion with interviewees and other members of their organizations (Birt et al. 2016; Motulsky 2021) . Interview contents and preliminary findings were shared and discussed through three focus groups/collaborative group sessions, two of which focused on reengaging with manager interviewees, and one that focused on the author/outreach group. These sessions were opportunities for feedback, discussion, and corroboration or complication of developing themes, and these thoughts were incorporated as coding and analysis continued. Authors of this article work for organizations that contributed to GTR-373 development, outreach, and implementation; this article is a continuation of the cooperative evaluation of GTR-373-based science communication, outreach and application that these organizations have pursued.

Results

Five important themes emerged during our interviews demonstrating how co-development and outreach built trust in the end product, how managers use GTR-373, and persistent challenges for managers using the framework. We report here on findings for which there was general consensus and share discreet insights from interviewees that illuminate differences in science application within our sample of the Colorado Front Range forest restoration community.

The Co-development Process Built Trust and Improved the End Product

Authors and intended end-users interacted extensively as the framework developed; managers were also members of the author team, resulting in an organizationally and experientially diverse author list. Managers reported that one of the key reasons they trusted the published document was the variety of organizations and individuals involved in the development process. Personal relationships, existing collaboratives, group discussion of monitoring results, wide dissemination of drafts, informal field visits, and organized field trips were all mentioned as important cross-boundary activities that built understanding of and trust in the final framework. They also provided opportunities for authors to share newly developed or synthesized research about local fire history and forest stand reconstruction data in advance of publication. Several GTR authors developed new research that was foundational to the GTR-373 framework (e.g., Aplet et al. 2014; Battaglia et al. 2018; Briggs, Fornwalt, and Feinstein 2017; Brown et al. 2015; Dickinson 2014; Fornwalt et al. 2016), and authors reported engaging in iterative conversations with managers about applying new and existing forest ecology knowledge on the ground. Thus, the concepts and models described in GTR-373 were being socialized and integrated into practice as the framework itself was being developed.

Information from managers was also reabsorbed into the developing GTR-373, as authors reported being informed by practical feasibility considerations and by what innovative managers were already doing on the ground with the science they had available to them. A few managers stated that they felt the authors of GTR-373 had captured and documented aspects of their experiential and institutional knowledge within the new framework. Managers from one non-federal organization and one Forest Service district stated that before the GTR-373 co-development process began, they had been adaptively managing Front Range ponderosa pine forests using concepts from other restoration frameworks for similar ecosystems that they modified for local context (e.g., Reynolds et al. 2013). The desire for a similar product to provide site-specific information for the Front Range was cited as a motivating factor for developing GTR-373.

A few authors expressed feeling that their inclusion in the author list was due more to their work facilitating knowledge transfer through one-on-one and small group conversations, extensive field visits, and content dissemination in advance of publication than their work as writers or data analysts. Managers and authors connected with each other consistently as GTR-373 developed, and many non-federal managers referenced the strength and importance of their relationships with members of the author team and their high level of comfort reaching out to GTR-373 authors to ask questions, arrange field visits, and make suggestions about GTR-373

as it was being developed. "We had those people on speed dial," said one non-federal manager (ID8). Both authors and managers reported that in-depth conversations that took place on frequent field visits were a valuable component of this process. During field visits, managers felt that authors of the GTR-373 restoration framework listened to and collaborated with them and asked questions about the decisions managers were making on the ground. Interviewees recalled that many conversations between managers and authors revolved around implementation and the feasibility of implementing GTR-373 concepts within existing operational and organizational constraints. These discussions during the co-development process built more trust in the final product: "Any effort to understand management constraints being factored into scientific work, and including those in research, shows that there's been thought, and I would trust that more" (Forest Service Manager ID2).

Authors also believed that although collaboration can lengthen the publication timeline, the process leads to increased understanding of the situation on the ground, which in turn improves the applicability of the science. In 2013, authors held two workshops for Forest Service staff to give feedback on an early GTR-373 draft. After these workshops, authors expressed that they went back to the drawing board to rethink how they were presenting and describing the concepts. Major revisions after this workshop incorporated feedback about how to increase applicability for the intended audience of managers. Authors stated that the next draft of the framework decreased jargon, focused on more manager concerns, and added more photos and figures. One manager recalled that each new version incorporated end-user feedback to reflect additional detail and applicability.

Interviewees reported the importance of existing collaborative efforts (i.e., FR-CFLRP, Roundtable) to support information exchange. For example, during "jam sessions" a variety of practitioners and researchers met to exchange results from monitoring of projects across the FR-CFLRP landscape and discuss how to use new information. Researchers working on a variety of projects would also present updates on recent and ongoing work that could be applicable to management practice on the Front Range, including the GTR-373 framework. Forest Service managers especially mentioned these opportunities as the primary way they were getting information about the GTR-373 concepts as they developed.

Communication and Outreach Efforts were Crucial for Science Application

Authors and managers reported that the communication and outreach efforts following publication of GTR-373 were major strengths of the process, though they required considerable effort and resources. A dedicated outreach team of science delivery professionals and members of the GTR-373 author team from multiple organizations collaboratively designed a multipronged outreach strategy to reach managers from many organizations on the Front Range. Author interviewees who were also members of the outreach team reported that rather than having one spokesperson, the team focused on developing consistent themes that could be presented by many voices to varied audiences. Outreach included multiple information exchanges with Forest Service leadership and staff from the Pike & San Isabel and Arapaho & Roosevelt National Forests and the Rocky Mountain Region (R2) Leadership Team. Informal "pub talks" reached broader interested audiences working in academia, forestry, fire, and restoration (see also Brown, Clark, and Mattor 2021). The outreach team also shared information about the GTR-373 framework through existing collaborative networks, professional organizations, and agency leadership listservs. The USDA Forest Service Rocky Mountain Research Station (RMRS) science delivery staff published and widely circulated two science briefs through their *Science You Can Use* publication series that summarized the main findings of GTR-373 (USDA Forest Service RMRS 2018a, 2018b). In interviews, managers highlighted the *Science You Can Use* series as products they use to understand the framework and communicate it to others, especially the public.

Importantly, the outreach team designed and hosted two large field workshops that were attended by over one hundred fifty forest management practitioners from a variety of organizations. Authors who participated on the outreach team reported that workshops were extremely time and resource intensive, but they were crucial opportunities to connect with audiences who hadn't been as deeply involved in the GTR-373 co-development process. Workshop evaluation surveys indicated that workshops were generally considered effective in communicating about the ideas and concepts in the document (Brown, Clark, and Mattor 2021). Authors reported that this level of outreach around a publication was unprecedented in their experience:

> *"The dedicated team to do the outreach was pretty amazing and impressive, the way all that came together went really well. Them developing an outreach plan, the authors doing presentations, it was a bit of a road show, but felt very well organized. The workshops themselves were highly organized and had great flow, it was a real feat. I can't think for that stage that anything more or better could have been done" (Author ID14).*

Managers who had not been involved in the co-creation of the framework reported hearing about GTR-373 through network connections, or from webinars, one of the field workshops that took place after publication, or RMRS *Science You Can Use* documents.

Managers use GTR-373 to Justify Management Action

In interviews, managers across all six organizations and at different levels of decision-making consistently reported that GTR-373 has provided *justification* for designing forest management actions in Front Range forests. Managers from every agency interviewed used the word "justification" to indicate that they had used GTR-373 to support an approach to forest management that focuses more on increasing heterogeneity as opposed to thin-from-below fuel treatments or timber. There was some concern among interviewees that agencies are implementing these concepts differently, and there may be many different interpretations of what it means to implement restoration principles according to GTR-373. Some interviewees further expressed their concern that not all practitioners have full understanding or investment in implementing GTR-373 principles, and because GTR-373 is used to justify actions, some projects may be implemented according to GTR-373 in name only, without any change to preexisting intentions or practices.

Interviewees specified situations in which GTR-373 had provided them with justification for management action. Many managers reported citing GTR-373 in silviculture reports, grant proposals, and other planning documents for forest restoration projects. Among Forest Service managers, GTR-373 has been a useful tool for communicating with leadership and navigating organizational barriers. For example, a Forest Service silviculturist reported using a draft of GTR-373 to justify a new restoration prescription to forest leadership. Managers have also used GTR-373 to justify their approaches to the public, external collaborators, and private landowners. Some non-federal managers noted in interviews their perception that landowners and neighbors have become more comfortable with increased density reduction and increased heterogeneity. Despite the progress related to public understanding and education that some organizations have reported, a majority of both Forest Service and non-federal managers said that one of the biggest challenges to implementing the science within the GTR-373 framework remains social acceptance. They shared that the scientific community and boundary spanning organizations can help address these barriers by making themselves available to speak at public meetings, creating public-facing communication tools and materials, and providing opportunities for the public to see managers and the research community interacting and working together.

The GTR-373 Framework Gives Managers a Common Foundation, but Agencies are Implementing the Framework Differently

In interviews, managers across jurisdictions explained their approaches to designing projects that implement concepts of forest heterogeneity and resiliency to disturbance—central themes in GTR-373. Some statements about manager goals noticeably complement one another:

> *"The ultimate goal of treatment is not about timber, it's about making [the forest] resilient for as many resources as possible."*
> *~Forest Service Manager ID10*

> *"We're not interested in growing trees; we're interested in sustainable acres."*
> *~Non-federal Manager ID7*

Managers from four non-federal organizations described GTR-373 as a foundational document that provides guiding principles for their organizations' ponderosa pine and dry mixed-conifer management on the Front Range. Managers from the Forest Service and non-federal agencies, and staff from one research agency reported using GTR-373 to train new and seasonal employees. There was general agreement that the published framework both provides a thorough and useful synthesis of locally relevant, actionable science and paints a larger picture to justify management action towards restoring historic forest structures.

In interviews, authors stated their intent for the GTR-373 to be a flexible set of guidelines supported by relevant science principles that practitioners and planners can use to develop shared understanding of desired future conditions for a project area, and design prescriptions to meet their objectives. Authors represented a variety of expertise and affiliations, supporting broad applicability across jurisdictional boundaries. To maintain flexibility, authors expressed that they explicitly avoided getting too prescriptive by including few specific metrics (e.g., explicit desired densities, recommended implementation methods, etc.) and focused instead on describing the ecological processes that produce heterogeneous forest structure. Managers reported using the GTR-373 framework to translate conceptual ideas about desired conditions into on-the-ground action across a variety of contexts:

> *"When it comes to us applying 373 on the ground, we're certainly not walking around with it in our back pocket and saying, 'page 72 says to do this,' it's more us understanding the concepts, framework, and guidelines and principles behind it, and we go out and put down our interpretation of that…" (Non-federal Manager ID8)*

Managers from different organizations reported different organizational barriers and mandates that influence their decisions towards creating the "final future forest," as one non-federal manager described it (ID9). Forest Service managers expressed feeling less flexibility to implement new concepts compared with those working on non-federal lands due to the need to adapt within existing plans and NEPA, contracting and operational constraints, leadership reluctance, and external resistance. Some non-federal managers said they feel as though they are heavily constrained by neighboring or private landowner desires and have to balance science with landowner preferences and organizational mandates. Meanwhile, non-federal managers from one agency expressed a high degree of confidence in their ability to communicate with and educate landowners about the concepts and get them on board.

Applying GTR-373 Concepts at the Appropriate Scale Is Challenging

Managers on all lands described the challenges of working at the stand scale while seeking to influence landscape-scale conditions. Our interview data reflected omnipresent issues around the CFLRP's goal of increasing pace and scale of work, including cost, public perception, staff capacity, translating concepts into prescriptions for contractors, and feasible access to treatment areas. We also found that challenges with scale manifest differently for Forest Service and non-federal managers. Generally, Forest Service managers work on larger treatment units—many FR-CFLRP projects were between 100 and 850 ac (Barrett et al. 2021), whereas a 200 ac treatment area could be considered a large project for most managers working on non-federal lands (Slack et al. 2021). Forest Service managers reported that one challenge of achieving landscape-scale heterogeneity is designing and communicating conceptual prescriptions to contractors when the project is physically large enough to preclude marking every acre. On non-federal lands, managers stated that they often complete detailed marking before cutting begins; on private lands this might include walking the property with the landowner to determine which individual trees to cut or leave. However, non-federal managers reported challenges trying to plan at a landscape scale with operations taking place on small parcels, which may or may not be adjacent. Non-federal managers reference the challenge of achieving heterogeneity—especially creating non-forested gaps—on small scales:

> *"The document comes from the perspective of being out in the middle of the Pike National Forest and you can do what you want. It doesn't acknowledge how to implement these concepts when you only have 40 acres to work with.*

Should I just really blow it out because I know the neighbors aren't going to do anything? Leave a few more trees because it's what the landowner wants?" (Non-Federal Manager ID7)

Despite the challenges that present themselves on the ground when doing the work, managers say the framework has influenced them to think about their projects in the context of a larger landscape while simultaneously thinking about how the landscape is influenced by any given project (Box 1). Managers across agencies expressed great interest in future monitoring to measure the impact their work on specific projects is having at a larger scale.

Discussion

This case study evaluates manager and researcher perceptions of the place-based knowledge co-development process that supported creation and publication of GTR-373 and examines the impact of that co-development for changes to practice and perception. Although there are many publications about restoration intended for use in practice and decision-making in specific ecosystems (e.g., North et al. 2009; Reynolds et al. 2013), rarely is the development and impact of a specific published resource so thoroughly evaluated. Throughout its development, the framework functioned to support and facilitate boundary-spanning activities between managers and authors. In practice, the completed GTR-373 is a boundary object applied across land ownerships and jurisdictions by both Forest Service and non-federal land managers.

Our findings are consistent with others that emphasize the collaborative process as an important outcome, perhaps as important as any end product (Armitage et al. 2011; Beeton, Cheng, and Colavito 2022; Cross et al. 2022; Raymond et al. 2010). The GTR-373 co-development process created structure for sustained engagement by individuals from multiple organizations, incentive to work across boundaries, and a space for iterative discussion that confirmed the framework would be useful for managers. In interviews, managers reported that the cross-boundary expertise and organization affiliations represented on the GTR-373 author list positively affected their intent to use the information. Managers are under pressure to use relevant science (Esch et al. 2018) and indicated in interviews that they were invested in engaging with researchers to apply new science findings to ongoing projects. Authors, including manager authors, were equally invested in developing applied science that could be incorporated into management decisions. It is well documented that participants in co-development processes feel more ownership over and confidence in co-produced knowledge, which can facilitate its use in decision-making and action (Briske et al. 2017; Cook et al. 2013; Cross et al. 2022; Cvitanovic et al. 2015; Dilling and Lemos 2011; Fazey et al. 2013; Feldman and Ingram 2009).

GTR-373 concepts and results from concurrent research were being socialized during development through multiple mechanisms, and no interviewees reported being wholly unfamiliar with GTR-373 concepts at the time of its publication (Brown, Clark, and Mattor 2021). As in other studies of what supports effective science application, relationships between managers and scientists and informal information exchange, often during field visits, remained a crucial component of the socialization process (Archie et al. 2014; Laatsch and Ma 2016; Timberlake and Schultz 2019; Yamamoto 2012). Repeated field visits, where managers and authors could discuss ideas together in the forest, were reported to be particularly impactful for increasing understanding and adoption of GTR-373 concepts into practice. Authors took feedback from these on-the-ground conversations and workshops where drafts of the framework were discussed, and continually revised GTR-373 to make it more salient and useable for the intended manager audience. Authors simultaneously monitored, documented, shared, and incorporated results from managers who were already applying the science and monitoring data to make GTR-373 more applicable. Some authors described these repeated interactions as transformative for their thinking about how to engage managers in their research process before results are published.

In practice, the published GTR-373 provides science-supported justification for taking management action in ponderosa pine and dry mixed-conifer forests on Colorado's Front Range. Managers report that they consider GTR-373 concepts, such as creating heterogeneity in age classes, forest structure, and tree arrangement, as they plan and design projects. Many non-federal managers stated that they use the GTR-373 framework as a foundational science synthesis and tool for their organization's work. Users at multiple types of organizations also reported that the document is used as a training tool for new and seasonal employees. GTR-373 serves as a vital boundary object that documents

Box 1. Example of a manager implementing a GTR-373 concept (forest gap creation), and using the framework to plan and communicate.

Managers implement GTR-373 concepts: creating forest gaps

When asked about addressing challenges implementing GTR-373, managers often mentioned the difficulty of increasing heterogeneity in forest structure. GTR-373 emphasizes the importance of creating forest gaps similar to the openings historically created by disturbance that would promote heterogeneity. Based on our evaluation, this concept seems to have translated well into understanding and practice among managers. During interviews, participants across ownerships and roles discussed the importance of creating and maintaining forest gaps to restore open components of the forest and address tree encroachment into meadows.

One manager (ID17) sought to create gaps in forested areas on private lands. They discussed the importance of forest gaps with landowners using messaging that emphasized the value of meadow restoration. However, gaps can be challenging to create on smaller private land parcels where landowner preference is typically to retain more trees. To avoid leaving landowners with no trees, the manager placed part of the gap on one property and continued the gap on an adjacent property. This is one example of how managers have shifted paradigms around the importance of heterogeneity to such an extent that they are willing to find creative solutions to implement the principle of heterogeneity in practice. This is also an example of how the GTR-373 empowered mangers to justify approaches and communicate with landowners to provide education on the importance of forest gaps.

and institutionalizes actionable working knowledge for any parties not involved in the co-production process.

Not all managers or authors agreed about how well treatments were being implemented across the landscape, and some felt certain projects were completed according to GTR-373 principles in name only. Complete alignment in cross-boundary practice is likely impossible; co-creators of boundary objects continually adapt them, adjusting information and its presentation to an acceptable balance for multiple interests (Star 2010; White et al. 2010). Boundary objects are inherently somewhat plastic, and as they are designed to apply across circumstances, they can be accessed and used by different practitioners for various purposes (Star and Griesemer 1989). They may also be valued differently across various audiences and in ways that suit individual interests (Cash et al. 2003). There may be additional benefits to variable cross-boundary application in creating heterogeneous landscapes. There has been concern in the years since the release of GTR-373 that configurations of trees applied to increase heterogeneity at the stand scale (e.g., tree groups and forest gaps) are being applied identically across the landscape, resulting in a new kind of homogeneous forest, albeit one that is less dense (Barrett et al. 2021; Cannon et al. 2018).

In addition, since publication of GTR-373, more information needs have been revealed and expressed. Authors and managers have reported concerns that some of the historic range of variability expectations for the Front Range may be altered by climate change and future fire (Davis et al. 2019; Stevens-Rumann et al. 2018), and the GTR-373 framework does not adequately address operational and planning concerns in a warmer, drier climate. Additionally, authors and managers recognize that the framework focuses on silviculture and does not include crosswalks to prefire planning and fire management, which are being integrated with forest management practices (Thompson et al. 2022).

As landscape-scale efforts are increasingly undertaken on public and adjacent lands, managers are challenged to act at the scale of a single project, and simultaneously think and plan projects in the context of a much larger social and biophysical landscape (Carter et al. 2020; Crausbay et al. 2022; Thompson et al. 2022). Managers reported funding, capacity, and feasibility barriers when operating on large scales. Lack of scientific information at appropriate scales for decision-making can also be a barrier to action (Archie et al. 2014; Carter et al. 2020). Although GTR-373 discusses how to use locally relevant ecological information to prioritize and design restoration projects across multiple scales, managers still report that they experience scale-related challenges on the ground when actually doing the work. We found that while trying to act in a landscape context, managers working on large, contiguous Forest Service lands face different challenges than those working on non-federal lands, and smaller private parcels.

However, the cross-boundary operating environment produced by the Front Range CFLRP incentivized collaboration and motivated managers to take innovative planning approaches at larger scales (Schultz et al. 2014, 2017, 2018). Moreover, the FR-CFLRP defined the conceptual scale at which GTR-373 needed to operate as a boundary object to support work (i.e., the scale of the Front Range). We heard from managers across organizations that GTR-373 concepts help them think about their projects in a landscape context and also to think about how the landscape is influenced by any given project.

Addressing scale mismatches in policy, science, and decision-making tools is an important component of incorporating knowledge into management practice and collaborative adaptive management (Archie et al. 2014; Schulz et al. 2018; Wurtzebach et al. 2019). Boundary-spanning activities and continued learning around boundary objects can build shared understanding and align expectations on particularly complicated topics, such as application of multiscalar concepts in practice (Blades et al. 2016; Cash et al. 2003; Shaw, Steelman, and Bullock 2022).

Continual engagement with GTR-373 authors and discussions of scale issues may have helped to build manager confidence in implementing at multiple scales. Many managers across ownerships have been able to apply the GTR-373 concepts in flexible, creative, and locally specific ways, informed by their individual organizations' mandates (Box 1). Outcomes of collective learning, implementation, and collaborative adaptive management are helping individual projects and partners have a larger cumulative impact across the Front Range landscape. For example, over time, forest treatments have better targeted larger reductions in small-diameter trees to better approximate historic forest conditions that contained higher ratios of larger-diameter trees (Barrett et al. 2021; Briggs, Fornwalt, and Feinstein 2017; Cannon et al. 2018). Projects aggregated in the Upper South Platte Watershed (a subarea within the FR-CFLRP) have also made progress towards forest structure and composition goals by breaking up large areas of contiguous forest with more interspersed meadows and increasing the ratio of ponderosa pine relative to other conifers (Slack et al. 2021). There is also evidence that some of the forest management done within the FR-CFLRP landscape helped change outcomes on the 2020 Cameron Peak Fire (Caggiano et al. 2021). These outcomes suggest that at least to some extent, GTR-373 has functioned to meet collaborative partners and empower them to act at the scale of their decision space. Co-creators of similar boundary objects could consider devoting extensive time to identifying, discussing, and addressing locally-specific scale issues and engaging in knowledge co-development that focuses specifically on implementation of concepts at various scales.

The development of GTR-373 supported boundary-spanning processes and knowledge co-development. The learning and adaptation process that we report on here continues to nurture collaboration across organizations on the Front Range (Huayhuaca et al. 2023). Cross-boundary authorship and participation in the GTR-373 development process resulted in a boundary object that has been incorporated into use in various organizational contexts. Shared learning embedded in collaborative process builds trust in and increases ownership of knowledge and is an important function for forest management collaboratives (Beeton, Cheng, and Colavito 2022; Fiske and Dupree 2014; Yamamoto 2012). Shared learning that is incentivized by sustained funding like the CFLRP and results in a collaboratively developed boundary object that has the flexibility and rigor to be incorporated by many organizations working at a variety of scales is capable of shifting perspectives and behavior (Beeton, Cheng, and Colavito 2022; Norström et al. 2020; Schultz et al. 2018). In the case of GTR-373, the process of creating the boundary object had transformative value for the community of practice.

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Conflict of Interest

None declared.

Data Availability

The data underlying this article are not publicly available to preserve anonymity of research participants. The data will be shared by reasonable request to the corresponding author.

Literature Cited

Addington, Robert N., Gregory H. Aplet, Mike A. Battaglia, Jennifer S. Briggs, Peter M. Brown, Antony S. Cheng, Yvette Dickinson, et al. 2018. *Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range*. USDA Forest Service General Technical Report RMRS-GTR-373. Fort Collins, CO: Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-373.

Aplet, Greg, Peter Brown, Jenny Briggs, Sara Mayben, Dick Edwards, and Tony Cheng. 2014. *Collaborative Implementation of Forest Landscape Restoration in the Colorado Front Range*. Technical Brief CFRI-TB-1403. Fort Collins, CO: Colorado Forest Restoration Institute.

Archie, Kelli M., Lisa Dilling, Jana B. Milford, and Fred C. Pampel. 2014. "Unpacking the 'Information Barrier': Comparing Perspectives on Information as a Barrier to Climate Change Adaptation in the Interior Mountain West." *Journal of Environmental Management* 133: 397–410. https://doi.org/10.1016/j.jenvman.2013.12.015.

Armitage, Derek, Fikret Berkes, Aaron Dale, Erik Kocho-Schellenberg, and Eva Patton. 2011. "Co-Management and the Co-Production of Knowledge: Learning to Adapt in Canada's Arctic." *Global Environmental Change* 21 (3): 995–1004. https://doi.org/10.1016/j.gloenvcha.2011.04.006.

Bamzai-Dodson, Aparna, Amanda E. Cravens, Alisa Wade, and Renee A. McPherson. 2021. "Engaging with Stakeholders to Produce Actionable Science: A Framework and Guidance." *Weather, Climate, and Society* 13 (4): 1027–1041. https://doi.org/10.1175/WCAS-D-21-0046.1.

Barrett, Kevin J., Jeffery B. Cannon, Alex M. Schuetter, and Antony S. Cheng. 2021. "Effects of Collaborative Monitoring and Adaptive Management on Restoration Outcomes in Dry Conifer Forests." *Forest Ecology and Management* 488: 119018. https://doi.org/10.1016/j.foreco.2021.119018.

Battaglia, Mike A., Benjamin Gannon, Peter M. Brown, Paula J. Fornwalt, Antony S. Cheng, and Laurie S. Huckaby. 2018. "Changes in Forest Structure Since 1860 in Ponderosa Pine Dominated Forests in the Colorado and Wyoming Front Range, USA." *Forest Ecology and Management* 422: 147–160. https://doi.org/10.1016/j.foreco.2018.04.010.

Beeton, Tyler A., Antony S. Cheng, and Melanie M. Colavito. 2022. "Cultivating Collaborative Resilience to Social and Ecological Change: An Assessment of Adaptive Capacity, Actions, and Barriers Among Collaborative Forest Restoration Groups in the United States." *Journal of Forestry* 120 (3): 316–335. https://doi.org/10.1093/jofore/fvab064.

Birt, Linda, Suzanne Scott, Debbie Cavers, Christine Campbell, and Fiona Walter. 2016. "Member Checking: A Tool to Enhance Trustworthiness or Merely a Nod to Validation?" *Qualitative Health Research* 26 (13): 1802–1811. https://doi.org/10.1177/1049732316654870.

Blades, Jarod J., P. Zion Klos, Kerry B. Kemp, Troy E. Hall, Jo Ellen Force, Penelope Morgan, and Wade T. Tinkham. 2016. "Forest Managers' Response to Climate Change Science: Evaluating the Constructs of Boundary Objects and Organizations." *Forest Ecology and Management* 360: 376–387. https://doi.org/10.1016/j.foreco.2015.07.020.

Briggs, Jennifer S., Paula J. Fornwalt, and Jonas A. Feinstein. 2017. "Short-Term Ecological Consequences of Collaborative Restoration Treatments in Ponderosa Pine Forests of Colorado." *Forest Ecology and Management* 395: 69–80. https://doi.org/10.1016/j.foreco.2017.03.008.

Briske, David D., Brandon T. Bestelmeyer, Joel R. Brown, Mark W. Brunson, Thomas L. Thurow, and John Tanaka. 2017. "Assessment of USDA-NRCS Rangeland Conservation Programs: Recommendation for an Evidence-based Conservation Platform." *Ecological Applications* 27 (1): 94–104. https://doi.org/10.1002/eap.1414.

Brown, Hannah, Nehalem Clark, and Kathie Mattor. 2021. *Outreach for a Forest Restoration Framework: Efforts, Successes, and Lessons Learned during Publication and Communication of RMRS-GTR-373*. CFRI-2109. Fort Collins, CO: Colorado Forest Restoration Institute.

Brown, Peter M., Michael A. Battaglia, Paula J. Fornwalt, Benjamin Gannon, Laurie S. Huckaby, Chad Julian, and Antony S. Cheng. 2015. "Historical (1860) Forest Structure in Ponderosa Pine Forests of the Northern Front Range, Colorado." *Canadian Journal of Forest Research* 45 (11): 1462–1473. https://doi.org/10.1139/cjfr-2014-0387.

Brown, Peter M., Merrill R. Kaufmann, and Wayne D. Shepperd. 1999. "Long-Term, Landscape Patterns of Past Fire Events in a Montane Ponderosa Pine Forest of Central Colorado." *Landscape Ecology* 14: 513–532.

Brown, Peter M., and Wayne D. Shepperd. 2001. "Fire History and Fire Climatology Along a 5° Gradient in Latitude in Colorado and Wyoming, USA." *Palaeobotanist* 50 (1): 133–140.

Caggiano, Michael D., Tyler A. Beeton, Benjamin M. Gannon, and James White. 2021. *The Cameron Peak Fire: Use of Potential Operational Delineations and Risk Management Assistance Product*, 16. CFRI-2106. Fort Collins, CO: Colorado Forest Restoration Institute.

Cannon, Jeffery B., Kevin J. Barrett, Benjamin M. Gannon, Robert N. Addington, Mike A. Battaglia, Paula J. Fornwalt, Gregory H. Aplet, et al. 2018. "Collaborative Restoration Effects on Forest Structure in Ponderosa Pine-Dominated Forests of Colorado." *Forest Ecology and Management* 424: 191–204. https://doi.org/10.1016/j.foreco.2018.04.026.

Carter, Sarah K., David S. Pilliod, Travis Haby, Karen L. Prentice, Cameron L. Aldridge, Patrick J. Anderson, Zachary H. Bowen, et al. 2020. "Bridging the Research-Management Gap: Landscape Science in Practice on Public Lands in the Western United States." *Landscape Ecology* 35: 545–560. https://doi.org/10.1007/s10980-020-00970-5.

Cash, David, William C. Clark, Frank Alcock, Nancy Dickson, Noelle Eckley, and Jill Jäger. 2003. *Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making*. Harvard University, John F. Kennedy School of Government KSG Working Papers Series, RWP02-046. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.372280.

Charmaz, Kathy. 2006. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. London: Sage Publications.

Cheng, Antony S., Andrea K. Gerlak, Lisa Dale, and Katherine Mattor. 2015. "Examining the Adaptability of Collaborative Governance Associated with Publicly Managed Ecosystems Over Time: Insights from the Front Range Roundtable, Colorado, USA." *Ecology and Society* 20 (1): 35. https://doi.org/10.5751/ES-07187-200135.

Cheng, A.S., Gregory H. Aplet, and Amy E.M. Waltz. 2019. "Challenges and Opportunities for Collaborative Adaptive Management in Forest Landscape Restoration." In *A New Era for Collaborative Forest Management: Policy and Practice Insights from the Collaborative Forest Landscape Restoration Program*, edited by William H. Butler and Courtney A. Schultz, 119–136. Abingdon, UK: Routledge/Earthscan.

Cook, Carly N., Michael B. Mascia, Mark W. Schwartz, Hugh P. Possingham, and Richard A. Fuller. 2013. "Achieving Conservation Science That Bridges the Knowledge–Action Boundary." *Conservation Biology* 27 (4): 669–678. https://doi.org/10.1111/cobi.12050.

Crausbay, Shelley D., Helen R. Sofaer, Amanda E. Cravens, Brian C. Chaffin, Katherine R. Clifford, John E. Gross, Corrine N. Knapp, et al. 2022. "A Science Agenda to Inform Natural Resource Management Decisions in an Era of Ecological Transformation." *BioScience* 72 (1): 71–90. https://doi.org/10.1093/biosci/biab102.

Creswell, John W., and J. David Creswell. 2018. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. Thousand Oaks, CA: SAGE Publications.

Cross, Molly S., Lauren E. Oakes, Heidi E. Kretser, Raymond Bredehoft, Paul Dey, Anika Mahoney, Noelle Smith, et al. 2022. "Tackling the Science Usability Gap in a Warming World: Co-Producing Usable Climate Information for Natural Resource Management." *Environmental Management* 70 (6): 881–895. https://doi.org/10.1007/s00267-022-01718-4.

Cvitanovic, C., A.J. Hobday, L. van Kerkhoff, S.K. Wilson, K. Dobbs, and N.A. Marshall. 2015. "Improving Knowledge Exchange among Scientists and Decision-Makers to Facilitate the Adaptive Governance of Marine Resources: A Review of Knowledge and Research Needs." *Ocean & Coastal Management* 112: 25–35. https://doi.org/10.1016/j.ocecoaman.2015.05.002.

Davis, Kimberley T., Solomon Z. Dobrowski, Philip E. Higuera, Zachary A. Holden, Thomas T. Veblen, Monica T. Rother, Sean A. Parks, et al. 2019. "Wildfires and Climate Change Push Low-Elevation Forests across a Critical Climate Threshold for Tree Regeneration." *Proceedings of the National Academy of Sciences* 116 (13): 6193–6198. https://doi.org/10.1073/pnas.1815107116.

Dickinson, Yvette. 2014. "Landscape Restoration of a Forest with a Historically Mixed-Severity Fire Regime: What Was the Historical Landscape Pattern of Forest and Openings?" *Forest Ecology and Management* 331: 264–271. https://doi.org/10.1016/j.foreco.2014.08.018.

Dilling, Lisa, and Maria Carmen Lemos. 2011. "Creating Usable Science: Opportunities and Constraints for Climate Knowledge Use and Their Implications for Science Policy." *Global Environmental Change* 21 (2): 680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Esch, Bryce E, Amy E. M. Waltz, Tzeidle N. Wasserman, and Elizabeth L. Kalies. 2018. "Using Best Available Science Information: Determining Best and Available." *Journal of Forestry* 116 (5): 473–480. https://doi.org/10.1093/jofore/fvy037.

Fazey, Ioan, Anna C. Evely, Mark S. Reed, Lindsay C. Stringer, Joanneke Kruijsen, Piran C. L. White, Andrew Newsham, et al. 2013. "Knowledge Exchange: A Review and Research Agenda for Environmental Management." *Environmental Conservation* 40 (1): 19–36. https://doi.org/10.1017/S037689291200029X.

Feldman, David L., and Helen M. Ingram. 2009. "Making Science Useful to Decision Makers: Climate Forecasts, Water Management, and Knowledge Networks." *Weather, Climate, and Society* 1 (1): 9–21. https://doi.org/10.1175/2009wcas1007.1.

Fiske, Susan T., and Cydney Dupree. 2014. "Gaining Trust as Well as Respect in Communicating to Motivated Audiences about Science Topics." *Proceedings of the National Academy of Sciences* 111 (supplement_4): 13593–13597. https://doi.org/10.1073/pnas.1317505111.

Fornwalt, Paula J., Laurie S. Huckaby, Steven K. Alton, Merrill R. Kaufmann, Peter M. Brown, and Antony S. Cheng. 2016. "Did the 2002 Hayman Fire, Colorado, USA, Burn with Uncharacteristic Severity?" *Fire Ecology* 12 (3): 117–132. https://doi.org/10.4996/fireecology.1203117.

Front Range Fuels Treatment Partnership Roundtable. 2006. *Living with Fire: Protecting Communities and Restoring Forests. Findings and Recommendations of the Front Range Fuels Treatment Partnership Roundtable*. Denver, CO: Front Range Fuels Treatment Partnership Roundtable.

Gibson, Barry, and Jan Hartman. 2014. *Rediscovering Grounded Theory: Back to the Future. In Rediscovering Grounded Theory*. London: SAGE Publications. https://doi.org/10.4135/9781529799620.

Huayhuaca, Ch'aska, A.S. Cheng, T.A. Beeton, J.S. Sanderson, A.W. Barton, A.D. Kimple, M.M. Colavito, et al. 2023. *Preparing Landscapes and Communities to Receive and Recover from Wildfire through Collaborative Readiness: A Concept Paper*. Fort Collins, CO: Southwest Ecological Restoration Institutes.

Jacobson, Nora, Dale Butterill, and Paula Goering. 2004. "Organizational Factors That Influence University-Based Researchers' Engagement in Knowledge Transfer Activities." *Science Communication* 25 (3): 246–259. https://doi.org/10.1177/1075547003262038.

Kaufmann, Merrill R., Peter Z. Fulé, William H. Romme, Kevin C. Ryan. 2005. "Restoration of Ponderosa Pine Forests in the Interior Western US after Logging, Grazing, and Fire Suppression." In: *Restoration of Boreal and Temperate Forests*, 1st ed, edited by John A. Stanturf, and Palle Madsen, 481–500. Boca Raton, FL: CRC Press.

Laatsch, Jamie, and Zhao Ma. 2016. "Climate-Change Communication Within Public Natural Resource Agencies: Lessons Learned From the U.S. Forest Service." *Society & Natural Resources* 29 (10): 1169–1185. https://doi.org/10.1080/08941920.2015.1107790.

Laurance, William F., Harko Koster, Monique Grooten, Anthony B. Anderson, Pieter A. Zuidema, Steve Zwick, Roderick J. Zagt, et al. 2012. "Making Conservation Research More Relevant for Conservation Practitioners." *Biological Conservation* 153: 164–168. https://doi.org/10.1016/j.biocon.2012.05.012.

Mattor, Katherine M., Antony S. Cheng, Brian Kittler, and Maureen McDonough. 2020. "Assessing Collaborative Governance Outcomes and Indicators across Spatial and Temporal Scales: Stewardship Contract Implementation by the United States Forest Service." *Society & Natural Resources* 33 (4): 484–503. https://doi.org/10.1080/08941920.2019.1665762.

Miles, Matthew B., A. Michael Huberman, and Johnny Saldana. 2014. *Qualitative Data Analysis: A Methods Sourcebook*, 3rd ed. Thousand Oaks, CA: Sage Publications.

Motulsky, Sue L. 2021. "Is Member Checking the Gold Standard of Quality in Qualitative Research?" *Qualitative Psychology* 8 (3): 389–406. https://doi.org/10.1037/qup0000215.

Norström, Albert V., Christopher Cvitanovic, Marie F. Löf, Simon West, Carina Wyborn, Patricia Balvanera, Angela T. Bednarek, et al. 2020. "Principles for Knowledge Co-Production in Sustainability Research." *Nature Sustainability* 3 (3): 182–190. https://doi.org/10.1038/s41893-019-0448-2.

North, Malcolm, Peter Stine, Kevin O'Hara, William Zielinski, and Scott Stephens. 2009. *An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests*. USDA Forest Service General Technical Report PSW-GTR-220. Albany, CA: Pacific Southwest Research Station. https://doi.org/10.2737/PSW-GTR-220.

Raymond, Christopher M., Ioan Fazey, Mark S. Reed, Lindsay C. Stringer, Guy M. Robinson, and Anna C. Evely. 2010. "Integrating Local and Scientific Knowledge for Environmental Management." *Journal of Environmental Management* 91 (8): 1766–1777. https://doi.org/10.1016/j.jenvman.2010.03.023.

Reynolds, Richard T., Andrew J. Sanchez Meador, James A. Youtz, Tessa Nicolet, Megan S. Matonis, Patrick L. Jackson, Donald G. DeLorenzo, and Andrew D. Graves. 2013. *Restoring Composition and*

Structure in Southwestern Frequent-Fire Forests: A Science-Based Framework for Improving Ecosystem Resiliency. USDA Forest Service General Technical Report RMRS-GTR-310. Fort Collins, CO: Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-310.

Schoennagel, Tania, Thomas T. Veblen, and William H. Romme. 2004. "The Interaction of Fire, Fuels, and Climate across Rocky Mountain Forests." *BioScience* 54 (7): 661–676. https://doi.org/10.1641/0006-3568(2004)054[0661:tioffa]2.0.co;2.

Schultz, Courtney, Kathleen Mclntyre, Laren Cyphers, Chad Kooistra, Autumn Ellison, and Cassandra Moseley. 2018. "Policy Design to Support Forest Restoration: The Value of Focused Investment and Collaboration." *Forests* 9 (9): 512. https://doi.org/10.3390/f9090512.

Schultz, Courtney A., Dana L. Coelho, and Ryan D. Beam. 2014. "Design and Governance of Multiparty Monitoring under the USDA Forest Service's Collaborative Forest Landscape Restoration Program." *Journal of Forestry* 112 (2): 198–206. https://doi.org/10.5849/jof.13-070.

Schultz, Courtney A., Theresa Jedd, and Ryan D. Beam. 2012. "The Collaborative Forest Landscape Restoration Program: A History and Overview of the First Projects." *Journal of Forestry* 110 (7): 381–391. https://doi.org/10.5849/jof.11-082.

Schultz, Courtney A., Kathleen B. McIntyre, Laren Cyphers, Autumn Ellison, Chad Kooistra, and Cassandra Moseley. 2017. *Strategies for Success under Forest Service Restoration Initiatives*, 60. Eugene, OR: Ecosystem Workforce Program Institute for a Sustainable Environment, University of Oregon.

Shaw, Ashley, Toddi Steelman, and Ryan Bullock. 2022. "Evaluating the Efficacy of GIS Maps as Boundary Objects: Unpacking the Limits and Opportunities of Indigenous Knowledge in Forest and Natural Resource Management." *Journal of Cultural Geography* 39 (1): 90–116. https://doi.org/10.1080/08873631.2021.2011683.

Slack, AW, Brett H. Wolk, Camille Stevens-Rumann, Hannah L.C. Brown, Kevin J. Barrett, Stephanie E. Mueller, Tori M. Hunter, Kat E. Morici, and Katarina J. Warnick. 2021. *Upper South Platte Watershed Monitoring Report: Learning from Forest Restoration Projects to Advance Landscape Resilience and Collaboration*. CFRI 2103. Fort Collins, CO: Colorado Forest Restoration Institute.

Star, Susan Leigh. 2010. "This Is Not a Boundary Object: Reflections on the Origin of a Concept." *Science, Technology, & Human Values* 35 (5): 601–617. https://doi.org/10.1177/0162243910377624.

Star, Susan Leigh, and James R. Griesemer. 1989. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science* 19 (3): 387–420. https://doi.org/10.1177/030631289019003001.

Stevens-Rumann, Camille S., Kerry B. Kemp, Philip E. Higuera, Brian J. Harvey, Monica T. Rother, Daniel C. Donato, Penelope Morgan, et al. 2018. "Evidence for Declining Forest Resilience to Wildfires under Climate Change." *Ecology Letters* 21 (2): 243–252. https://doi.org/10.1111/ele.12889.

Thompson, Matthew P., Christopher D. O'Connor, Benjamin M. Gannon, Michael D. Caggiano, Christopher J. Dunn, Courtney A. Schultz, David E. Calkin, et al. 2022. "Potential Operational Delineations: New Horizons for Proactive, Risk-Informed Strategic Land and Fire Management." *Fire Ecology* 18 (1): 17. https://doi.org/10.1186/s42408-022-00139-2.

Timberlake, Thomas J., and Courtney A. Schultz. 2019. "Climate Change Vulnerability Assessment for Forest Management: The Case of the U.S. Forest Service." *Forests* 10 (11): 1030. https://doi.org/10.3390/f10111030.

USDA Forest Service Rocky Mountain Research Station. 2018a. *Back to the Future: Building Resilience in Colorado Front Range Forests using Research Findings and a New Guide for Restoration of Ponderosa and Dry-Mixed Conifer Landscapes*. Science You Can Use Bulletin 28. Fort Collins, CO: USDA Forest Service Rocky Mountain Research Station.

USDA Forest Service Rocky Mountain Research Station. 2018b. *Building Resilience in Colorado Front Range Forests for the Future*, 2. Science You Can Use in 5 Minutes. Fort Collins, CO: USDA Forest Service Rocky Mountain Research Station.

Veblen, Thomas T. 2003. "Historic Range of Variability of Mountain Forest Ecosystems: Concepts and Applications." *Forestry Chronicle* 79 (2): 223–226. https://doi.org/10.5558/tfc79223-2.

White, Dave D., Amber Wutich, Kelli L. Larson, Patricia Gober, Timothy Lant, and Clea Senneville. 2010. "Credibility, Salience, and Legitimacy of Boundary Objects: Water Managers' Assessment of a Simulation Model in an Immersive Decision Theater." *Science and Public Policy* 37 (3): 219–232. https://doi.org/10.3152/030234210x497726.

Wurtzebach, Zachary, Courtney A. Schultz, Amy E. M. Waltz, Bryce E. Esch, and Tzeidle N. Wasserman. 2019. "Adaptive Governance and the Administrative State: Knowledge Management for Forest Planning in the Western United States." *Regional Environmental Change* 19 (8): 2651–2666. https://doi.org/10.1007/s10113-019-01569-6.

Yamamoto, Yuri T. 2012. "Values, Objectivity and Credibility of Scientists in a Contentious Natural Resource Debate." *Public Understanding of Science* 21 (1): 101–125. https://doi.org/10.1177/0963662510371435.