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BRIDGING POST-WILDFIRE COMMUNICATION GAPS BETWEEN MANAGERS, RESEARCHERS, AND LOCAL COMMUNITIES, INCLUDING A BIOLOGICAL SOIL CRUST CASE STUDY

by

Hilary Louise Whitcomb

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Ecology

Approved:

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Logan, Utah

2017

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ABSTRACT

Bridging Post-Wildfire Communication Gaps between Managers, Researchers, and Local Communities, Including a Biological Soil Crust Case Study

by

Hilary L. Whitcomb, Doctor of Philosophy

Utah State University, 2017

Major Professor: Dr. Mark W. Brunson
Department: Ecology

Following a wildfire, land management agencies act quickly to protect ecosystem services. We don't currently understand how post-wildfire managers make trade-off decisions in these tight timelines, or if these decisions reflect current science. Using Brunson's (2014) social-ecological systems multi-scalar model, surveys assessed manager opinions about post-wildfire projects, perceptions of stakeholder opinions, and ability or willingness to consider new science results. Public surveys asked local citizens their opinions about post-wildfire projects. Manager perceptions were measured through semi-structured phone interviews ($n = 8$) and a structured online survey ($n = 256$). Public surveys were mailed to 1,000 (971 deliverable, $n = 152$ usable) residents in rural and urban Great Basin and Mojave Desert ZIP codes. We found coarse- and fine-scale social and political opinions were associated with all post-wildfire management decisions, often creating perceived barriers to project implementation. Conversely, local citizens were more supportive of projects than managers perceived them to be. While the majority of managers and citizens supported the concept of incorporating experimental research, managers were less able to consider more specific research incorporation into actual projects.

Ecologically, biological soil crusts (BSC) are emerging as an important fine-scale component of semi-arid restorations. However, even when BSCs are assessed prior to a restoration plan, it is unclear how or if this knowledge has any impact. BSCs were evaluated both socially and ecologically: all manager surveys contained questions specifically related to BSC, and a pilot greenhouse study assessed a) if seed drilling simulations on different stages of BSC may affect restoration plant establishment and b) if BSC excluded the invasive species *Bromus tectorum*. Similar to other new science results, managers were unlikely to be able/willing to consider BSC status in post-wildfire projects. However, our results suggest the possibility that, even when lightly burned, seeding strategy may influence native plant establishment. In ideal greenhouse conditions, *B. tectorum* was able to establish readily on both burned and unburned BSC.

(320 pages)

PUBLIC ABSTRACT

Bridging Post-wildfire Communication Gaps between Managers, Researchers, and Local Communities, Including a Biological Soil Crust Case Study

Hilary L. Whitcomb

Immediately after a wildfire land managers act quickly to protect water supplies, soil stability, habitat, and forage. We don't currently understand how managers make trade-off decisions between social, political, and ecological factors in these tight timelines or if they are able to use new science. We do know ecosystems often benefit from local engagement, and new, scientifically-grounded methods that improve restoration efforts are needed. As post-wildfire timelines don’t often allow for outside input, I asked managers what they and stakeholders think about post-wildfire projects and what managers think about new science. I asked local citizens what they think about post-wildfire projects. Social and political factors weighed heavily on most manager decisions and their ability to consider research. Managers were not very good at interpreting actual local citizen opinions, highlighting the need for communication.

In semi-arid and arid desert systems, biological soil crusts (BSC) provide soil stability, seed protection, and increase nutrients and water to plants. We don’t really know if restoration techniques that disturb biological soil crusts impact the success of projects. I asked managers if they thought BSC condition in post-wildfire projects is important and I conducted a preliminary greenhouse study to see if disturbing BSC impacted establishment of common restoration grasses and wildflowers. Most managers were not interested in BSC condition. Our greenhouse results suggest BSC disturbance may affect plant establishment, and follow-up field studies can be recommended.

ACKNOWLEDGMENTS

I would like to thank my committee members Drs. Eugene Schupp, Ryan Bosworth, Kari Veblen, and Janis Boettinger for their support and assistance throughout this process. I would especially like to thank Dr. Mark Brunson for his guidance, support, patience, and wisdom for the past eight years.

I give special thanks to my family, friends, and colleagues for their encouragement, patience, and moral support throughout this process. Josh for your constant support and perspective. My kids, Benji and Jamie, for pure motivation and necessary giggles. And sincere thanks to Cafe Ibis for fueling the majority of my dissertation—your delicious locally roasted coffee was a constant panacea, both spiritually and realistically. I wish I could have afforded you once my funding ran out.

Hilary L. Whitcomb

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CHAPTER 1

INTRODUCTION

Semi-arid and arid landscapes have proven extremely difficult to restore, particularly when ecological thresholds are crossed (Knapp 1996). Invasive plant species in the Great Basin and Mojave Desert have created changes in disturbance regimes, soil legacies, and ecosystem hydrology (Rau et al. 2007). These changes can have vast and diverse effects on biotic interactions (Davies et al. 2012; Brooks et al. 2015) and ecosystem services (Graaff et al. 2015). Recent research suggests past restoration practices may have minimal impact on long-term and even some short-term (< 20 years) goals (Knutson et al. 2014, Arkle et al. 2014). Indeed, wildfires and their associated costs are increasing rapidly across these systems (Whisenant 1990; Pilliod and Welty 2013). In the Great Basin between 1990 and 2013, public land agencies conducted at least 1,600 post-fire rehabilitation treatments on 2.2 million ha, or 6%, of the region (Pilliod and Welty 2013). Recent estimates indicate wildfires burn up to 1 million ha of Great Basin lands each year, increasing the number of post-wildfire treatments. In 2007 alone, $60 million was spent on Emergency Stabilization and Rehabilitation (ESR) projects on federal lands. Given this enormous dedication of resources to post-wildfire rehabilitation in the Great Basin, finding pathways that can improve incorporation of new research is important.

New research and techniques are certainly not lacking, yet even relatively more established strategies are subject to implementation barriers (USGAO 2003; USGAO 2006; Wright 2010). Interagency wildland fire policy (USDA and USDI 2003) mandates the use of “best available science” as well as quickly implementing new science on post-wildfire projects. Yet the sheer volume of research and context-dependent nature of land management, make synthesis into actual rehabilitation plans difficult (Wright 2010).

While land manager decisions are largely shaped by agency policy and institutional cultural norms (Weick and Sutcliffe 2011), managed ecosystems are by definition social-ecological systems (Brunson 2012, 2014). The context-dependent nature of ecological restorations is equally true for the social-political characteristics of each project. Encouraging restorations that promote connectivity across socio-political borders (a factor of significant ecosystem importance) requires an understanding of social-political-ecological contexts, all of which vary spatially-temporally. Though often overlooked historically, stakeholder knowledge, preferences, and goals can have a significant impact on management success and may help reduce uncertainty in management decisions (Peterson and Coppock 2001; Knapp and Fernandez-Gimenez 2009; Hallett et al. 2013). This research explores the relative strength of different options managers are able to "trade off" within the bounds of policy and social pressures (e.g., for the same cost, does a manager choose the better seeding tool or treating more acres). Trade-off decisions (what managers value most) were couched within the concept of coarse- and fine-scale factors (Brunson 2014, see Fig. 1.1) and tested with semi-structured interviews and structured surveys. Coarse-scale variables refer to those social, political, and ecological variables that occur outside of the landscape level (e.g., national policy), while fine-scale variables occur within the landscape (e.g., local stakeholders).

The studies described herein also tested managers' ability or willingness to incorporate new research results into their projects. "Innovation adoption" is defined as the experimentation, diffusion, and eventual incorporation of new practices into current

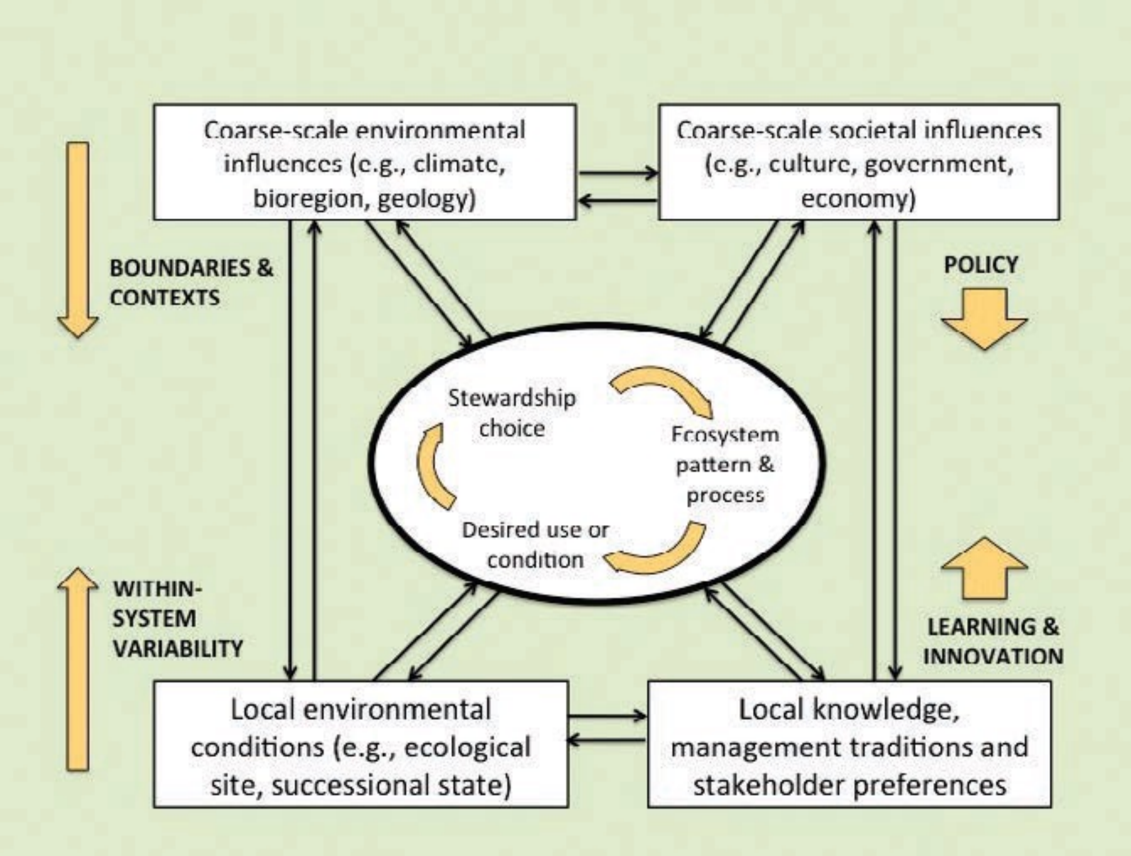

Coarse-scale environmental influences (e.g., climate, bioregion, geology)
Coarse-scale societal influences (e.g., culture, government, economy)
BOUNDARIES & CONTEXTS
POLICY
Stewardship choice
Ecosystem pattern & process
Desired use or condition
WITHIN-SYSTEM VARIABILITY
LEARNING & INNOVATION
Local environmental conditions (e.g., ecological site, successional state)
Local knowledge, management traditions and stakeholder preferences

Fig. 1.1. Multi-scalar model attempts to fill communication gaps in post-wildfire projects using a multi-scalar model of social-ecological systems (Brunson 2014). In this model coarse- and fine-scale social-political and ecological variables create iterative feedbacks on decision making and ecosystem patterns.

management (Rogers 1995). Innovation adoption has been well studied for both private landowners and public land managers regarding prescribed fire, fuels reduction, and volunteer use. However, I know of no studies exploring these populations' opinions and the likelihood of adopting post-wildfire restoration innovations.

While Innovation Adoption Theory (discussed in depth in Chapter 3) provides a rigorous foundation for science uptake in organizations, it may be limited by its focus on unidirectional approaches. Unidirectional approaches (Rogers 2003 and Wright 2010) to innovation adoption incorporate potentially useless steps, as the general premise is to convince an end-user of the utility of a product or technique, without ascertaining end-users' actual ability or willingness to incorporate the technique until much later in the process. For example, in the Rocky Mountain Research Station Science Application and Integration Program (USFS 2004), the cycle of science distribution does not include the end-user until the Delivery and Trial stage (Problem Formulation → Research →Interpretation → Development → Delivery and Trial → Adoption → Problem Formulation). A Translational Ecology framework (Chapters 2 and 3) expands upon Innovation Adoption approaches by encouraging communication that accommodates iterative and adaptive learning processes (Brunson and Baker 2015). The same RMRS cycle can be applied, but by incorporating collaboration, translational approaches suggest the complicated efforts to convince specific managers and stakeholders of research utility can be discarded. Translational-style collaborations have been shown to increase trust and encourage social resilience to social, political, and environmental disturbances (Daniels and Walker 1996; Walker and Salt 2006; Cabin 2007; Palmer et al. 2007; Manning 2009; Coppock et al. 2015; McKinley et al. 2015)

While Translational Ecology and other SES collaborations are increasing in environmental management, institutional capacity for translational projects after a wildfire remains elusive. Thus, in this study, translational concepts were applied using a social-ecological systems multi-scalar model (Brunson 2012, 2014) to fill these gaps in understanding and communication between post-wildfire public land managers, researchers, and stakeholders (Figure 1.1 from Brunson 2014). The arrows in Figure 1.1 represent influences on management decisions, many of which entail making cost-benefit analyses, or trade-off decisions. Trade-off decisions weigh coarse- and fine-scale social, political, and ecology variables (e.g., are project choices based on livestock grazing or ecological severity). Understanding trade-off decisions may provide a collaborative bridge between management decisions and researchers and policy makers. Innovation adoptions are a type of trade-off decision important to researchers developing new techniques. In this study, managers' ability and willingness to consider new research results was explored as a collaborative bridge between managers and researchers. In public surveys I explored citizen preferences for post-wildfire restoration decisions. Of course, citizens also weigh coarse- and fine-scale social, political, and ecological variables; understanding how those variables may influence their ecological preferences is important and may provide valuable insight for preventing some NEPA appeals. Increasing our knowledge about post-wildfire citizen preferences may provide a collaborative bridge between stakeholders, managers, and researchers.

As costs and time considerations represent significant barriers to post-wildfire managers in particular (Wright 2010; Pilliod and Welty 2013), and to provide better translational feedback to researchers regarding public land manager innovation adoption potential, I propose a four-level framework that describes an innovation's degree of novelty and condition of barriers (Fig. 1.2). This framework is based on "Best Management Practices," "New Methods," and a "Cost-Time-Value (CTV) lens." We defined the CTV lens using Innovation Diffusion concepts (Rogers 1995). *Cost* and *time*¸ in addition to their self-evident definitions, also include the compatibility of a new technique with current practices and a manager's ability to conduct small trials in new projects. *Value* encompasses the relative advantage of a new technique compared to previous methods, the complexity of the technique, and a managers' ability to observe

“Best Management Practices” Low CTV *Most likely*	Best Management Practices High CTV
New methods Low CTV	New methods High CTV *Least likely*

Fig. 1.2. Public lands manager innovation framework: Cost-Time-Value (CTV) lens refers to cost, time, and/or perceived value of proposed innovation.

results. More detailed examples and definitions of the CTV lens can be found in Chapter 3, Methods. Land managers’ CTV barriers were examined in semi-structured interviews and used to predict general land manager support of innovations and research presented. On rangelands, ‘best management practices’ follow Natural Resources Conservation Service Technical Guide recommendations (USFS 2012). Here we use best management practices to refer to common practices used on the majority of post-wildfire projects in western United States semi-arid rangelands.

Social theories relevant to the research presented in the following two chapters included: Theory of Planned Behavior (Ajzen 1991), Applied Behavior Analysis (Skinner 1953), Norm Theory (Hovland et al. 1953), Capture Theory (Barney and Nader 1974), and Adoption-Diffusion Theory (Rogers 1995). Additionally, a Translational Ecology approach suggests iterative feedbacks can improve social-ecological communication (Brunson and Baker 2015). I used a translational framework to answer and test the following questions and hypotheses and provide feedback to managers and researchers: what do managers and the public think of post-wildfire projects? Which factors (social, ecological, political) do managers most value? Do manager and public/taxpayer attitudes align? Do managers feel policy supports post-wildfire considerations? In addition to these basic questions, we hypothesized:

- Hypothesis 1: Personal characteristics will influence managers' attitudes concerning post-wildfire projects and new research.
- Hypothesis 2: Concerns about changing climate as well as wildfire risks to personal property will influence attitudes about post-wildfire projects and research.
- Hypothesis 3: Increased exposure to local norms and manager perceptions of local community attitudes will predict manager attitudes toward post-wildfire projects and research.
- Hypothesis 4: Cost-time variables will influence manager attitudes toward research.
- Hypothesis 5: Coarse- and fine-scale social, political, and ecological variables will influence public land managers' and local communities' attitudes toward post-wildfire projects and research.

Biological Soil Crusts and Post-Fire Reseeding: A Translational Case Study

Biological soil crusts (BSCs) are communities of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria that inhabit semi-arid and arid ecosystems worldwide (Belnap et al. 2003). These complex communities colonize the top few millimeters of soil, binding and stabilizing soil particles (Cameron 1966; Belnap and Gardner 1993; St. Clair and Johansen 1993; Belnap and Eldridge 2003; Chaudhary et al.

2009), affecting soil properties and nutrient cycling (Harper and Marble 1988; Johansen et al. 1993; Harper and Belnap 2001), occupying niches otherwise avoided by native plants (Belnap and Eldridge 2003) while also providing seed and seedling microsites (St. Clair et al. 1984; Harper and Marble 1988; Belnap et al. 2001), and altering water runoff patterns, infiltration (Maestre et al. 2002), and retention (Brotherson and Rushforth 1983; Campbell et al. 1989; Gold and Bliss 1995; Fierer and Gabet 2002). BSCs represent an integral component of many landscapes and can be used as indicators of rangeland health (Pellant et al. 2000; Tongway and Hindley 2000). Soil properties may also contribute to the success or failure of some restoration projects (Rau et al. 2014).

While intact BSCs benefit most plants through increased nutrient and water availability, native species may be more able to access these resources than non-natives (Belnap et al. 2003; Morgan 2006; Dienes et al. 2007; Hernandez and Sandquist 2011) Indeed, studies have demonstrated that BSC may even inhibit establishment of the cool-season annual invasive grass *Bromus tectorum* L. (cheatgrass) (Larsen 1995; Howell 1998; Serpe et al. 2006; Dienes et al. 2007) and other noxious weed establishment (Hernandez and Sandquist 2011) while facilitating or having no effect on many native species from annual grasses to perennial forbs (St. Clair et al. 1984; Harper and St. Clair 1985; Eckert et al. 1986; Larsen 1995; Howell 1998; Bashkin et al. 2003; Hernandez and Sandquist 2011). As BSCs exist worldwide, including where cheatgrass is native, BSC inhibition of cheatgrass may partially explain this species’ evolutionary need for a high reproductive output. Additionally, cheatgrass invasion in the Great Basin has resulted in a positive feedback relationship with wildfire (Pechanec and Hull 1945; Whisenant 1990). Conversely, from a plant community perspective, BSC presence has demonstrated a positive correlation with native species richness and cover (Kleiner and Harper 1977; Jeffries and Klopatek 1987). Yet even when BSC are assessed prior to a post-wildfire project, altering seeding methods to account for potential BSC damage may be unlikely (Whitcomb unpublished data).

Fire inevitably decreases BSC biomass, cover, diversity (Johansen 1993, Johansen et al. 1982, 1984, Hilty et al. 2004), and ecosystem services (Johansen et al. 1998). However, BSCs also exhibit some resistance (minimal change in structure or function) to fire (Johansen 2001; Bowker et al. 2004; Warren et al. 2015). Even dead sheath material can continue to hold particles together, aggregating soil macronutrients and water and keeping dust production down (Belnap 2006). When BSCs are disturbed they provide a temporary pulse of resources, such as increased availability of soil nitrogen (Larsen 1995; Howell 1998). However, physical disturbance of BSC results in loss of structural and possibly chemical barriers to non-natives, changing physical competition dynamics of the system (Belnap et al. 2003; Serpe et al. 2006). While these disturbance mechanisms may also aid native plants in the absence of competition, invaders are often able to take advantage of nutrient pulses and reduced barriers much more effectively and rapidly (D'Antonio and Vitousek 1992; Larsen 1995).

Post-fire stabilization and rehabilitation seeding or other treatment strategies may further damage BSC, although some have argued the benefits of revegetation efforts may outweigh the ecological cost of this damage (Hilty et al. 2004; Pyke et al. 2013). New research is assessing the defensibility of that belief, even with regards to soil stabilization (Arkle et al. 2014; Knutson et al. 2014). Minimum-till drills and no-till drills that have less impact on BSC can be used, but have higher costs (both monetary and logistic) associated with them and cannot be used on all sites (e.g., slope constraints).

The relationship between BSC response/recovery post-seeding strategy has only been investigated in the Great Basin by one study (Aanderud 2014); target vegetation response based on BSC post-wildfire and post-drilling response has not been assessed in the Great Basin. Do different types of soil disturbance affect different functional/ morphological stages of BSC enough so that we see significant differences in target plant responses (e.g., threshold dynamics, alternative stable states)? Understanding the relationship between BSC response and target plant response to different seeding strategies may be valuable information both for ecologists in building ecosystem models and for land managers developing rehabilitation proposals.

Perceived logistical difficulty identifying BSC may be one reason rangeland managers do not always assess biological soil crust status (West 1990). In social science this represents an aspect of The Theory of Planned Behavior (Ajzen 1991), which postulates that before a behavior is changed, it must be considered within a person's control and of acceptable difficulty (self-efficacy). However, when BSC is assessed in Great Basin and Mojave Desert landscapes, protocols most likely to be used (e.g., "Interpreting Indicators of Rangeland Health," Pellant et al. 2005) may be too simplistic, missing or misunderstanding certain important ecological aspects of BSC communities (discussed at length in Chapter 4). The BSC study presented herein provides initial exploratory information regarding the following question: Does it matter to post-fire restoration success whether BSC group is recorded and monitored? Does it matter when different seeding strategies are used? As very little previous research exists on this topic, I approached this question with a pilot study, simply to see if any trends exist that may be worthy of further study.

In Chapters 2 and 3 I make the argument that effective translational ecology and diffusion of innovations both require iterative feedbacks at every stage of research development. As a manager-researcher-public collaboration was not possible for this project, I explored BSC attitudes and potential ecological importance from three directions. In Chapter 2 I asked managers in semi-structured interviews how and if they consider BSC in their post-wildfire decisions. In Chapter 3, using the translational framework and CTV lens, I assessed manager ability and willingness to consider BSC research. In Chapter 4 I conducted a pilot study assessing if damage to BSC sustained through restoration treatment influences restoration seedling establishment. I am continuing to explore the social context of BSC in a conjoint choice experiment that includes BSC to determine relative influences of social, political, and ecological variables on specific decision-making scenarios (e.g., choosing between a seeding strategy and native vs. non-native seed selection based on different social, political, and ecological variables).

References

Aanderud, Z, 2014. Biological soil crusts and fire in Utah’s West Desert [Fact sheet]. In Desert Fire, Mammal, and Plant Studies. Available at: http://desert-fmp.org/wp-content/uploads/2014/06/Aanderud-fact-sheet.pdf (Accessed 15 March 2017).

Ajzen, I, 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179-211.

Arkle, RS, Pilliod, DS, Hanser, SE, Brooks, ML, Chambers, JC, Grace, JB, Wirth, TA, 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere, 5(3), 31.

Barney, DR, Nader, R, 1974. The Last Stand. Grossman Publishers, City, State, 185 pp.

Bashkin, M, Stohlgren, TJ, Osaki, Y, Lee, M, Evangelista, P, Belnap J, 2003. Soil characteristics and plant exotic species invasions in the Grand Staircase-Escalante National Monument, Utah, USA. Applied Soil Ecology, 22, 67–77.

Belnap, J, 2006. The potential roles of biological soil crusts in dryland hydrologic cycles. Hydrological processes, 20(15), 3159-3178.

Belnap, J, Büdel, B, Lange, OL, 2003. Biological soil crusts: characteristics and distribution. In: Belnap, J, Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management, Springer-Verlag: Berlin, pp. 3–30.

Belnap, J, Eldridge, D, 2003. Disturbance and recovery of biological soil crusts. In Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 363-383.

Belnap, J, Gardner, JS, 1993. Soil microstructure in soils of the Colorado Plateau: the role of the cyanobacterium Microcoleus vaginatus. Western North American Naturalist, 53(1), 40-47.

Belnap, J, Prasse, R, Harper, KT, 2001. Influence of biological soil crusts on soil environments and vascular plants. In Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 281-300.

Bowker, MA, Belnap, J, Rosentreter, R, Graham, B, 2004. Wildfire-resistant biological soil crusts and fire-induced loss of soil stability in Palouse prairies, USA. Applied Soil Ecology, 26(1), 41-52.

Brooks, ML, Matchett, JR, Shinneman, DJ, Coates, PS, 2015. Fire patterns in the range of greater sage-grouse, 1984-2013-Implications for conservation and management. Page 66. U.S. Geological Survey Open-File Report 2015-1167.

Brotherson, JD, Rushforth, SR, 1983. Influence of cryptogamic crusts on moisture relationships of soils in Navajo National Monument, Arizona. Western North American Naturalist, 43(1), 73-78.

Brunson, MW, 2012. The elusive promise of social-ecological approaches to rangeland management. Rangeland Ecology and Management, 65(6), 632-637.

Brunson, MW, 2014. Unwanted no more: land use, ecosystem services, and opportunities for resilience in human-influenced shrublands. Rangelands 36(2), 5-11.

Brunson, MW, Baker, MA, 2015. Translational training for tomorrow's environmental scientists. Journal of Environmental Studies and Sciences, 1-5.

Cabin, RJ, 2007. Science-Driven Restoration: A Square Grid on a Round Earth? Restoration Ecology, 15(1), 1-7.

Cameron, RE, 1966. Desert algae: soil crusts and diaphanous substrata as algal habitats. Jet Propulsion Lab Technical Report, 32–971, pp. 1–41.

Campbell, SE, Seeler, JS, Golubic, S, 1989. Desert crust formation and soil stabilization. Arid Land Research and Management, 3(2), 217-228.

Chaudhary, VB, Bowker, MA, O'Dell, TE, Grace, JB, Redman, AE, Rillig, MC, Johnson, NC, 2009. Untangling the biological contributions to soil stability in semiarid shrublands. Ecological Applications, 19(1), 110-122.

Coppock, DL, Fernández-Giménez, M, Hiernaux, P, Huber-Sannwald, E, Schloeder, C, Valdivia, C, Arrendondo, J, Jacobs, M, Turin, C, and Turner, M, 2015. Rangelands in developing nations: conceptual advances and societal implications. In: Briske, D (Ed.), Rangeland Systems: Processes, Management, and Challenges. Springer.

Daniels, SE, Walker, GB, 1996. Collaborative learning: improving public deliberation in ecosystem-based management. Environmental impact assessment review, 16(2), 71-102.

D'Antonio, CM, Vitousek, PM, 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual review of ecology and systematics, 23, 63-87.

Davies, GM, Bakker, JD, Dettweiler-Robinson, E, Dunwiddie, PW, Hall, SA, Downs, J, Evans, J, 2012. Trajectories of change in sagebrush steppe vegetation communities in relation to multiple wildfires. Ecological Applications, 22, 1562-1577.

Dienes, L, Rosentreter, R, Eldridge, DJ, Serpe, MD, 2007. Germination and seedling establishment of two annual grasses on lichen-dominated biological soil crusts. Plant Soil, 295, 23–35

Eckert Jr., RE, Peterson, FF, Meurisse, MS, Stephens, JL, 1986. Effects of soil-surface morphology on emergence and survival of seedlings in big sagebrush communities. Journal of Range Management, 414-420.

Fierer, NG, Gabet, EJ, 2002. Carbon and nitrogen losses by surface runoff following changes in vegetation. Journal of Environmental Quality, 31(4), 1207-1213.

Gold, WG, Bliss, LC, 1995. Water limitations and plant community development in a polar desert. Ecology, 1558-1568.

Graaff, KA, Welty, J, Spaete, L, Dhakal, S, Baun, C, 2015. Quantifying and predicting fuels and the effects of reduction treatments along successional and invasion gradients in sagebrush habitats. Available at: https://www.firescience.gov/projects/11-1-2-30/project/11-1-2-30_final_report.pdf (Accessed 15 March 2017).

Hallett, LM, Diver, S, Eitzel, MV, Olson, JJ, Ramage, BS, Sardinas, H, Statman-Well, Z, Suding, KN, 2013. Do we practice what we preach? Goal setting for ecological restoration. Restoration Ecology, 21:312-319.

Harper, KT, Belnap, J, 2001. The influence of biological soil crusts on mineral uptake by associated vascular plants. Journal of Arid Environments,47(3), 347-357.

Harper, KT, Marble, JR, 1988. A role for nonvascular plants in management of arid and semiarid rangelands. In: Tueller, PT (Eds.), Vegetation science applications for rangeland analysis and management, Springer Netherlands, pp. 135-169.

Harper, KT, St. Clair, LL, 1985. Cryptogamic soil crusts on arid and semiarid rangelands in Utah: effects on seedling establishment and soil stability. Final report Bureau of Land Management, Utah State Office, Salt Lake City, 76 pp.

Hernandez, RR, Sandquist, DR, 2011. Disturbance of biological soil crust increases emergence of exotic vascular plants in California sage scrub. Plant Ecology, 212(10), 1709-1721.

Hilty, JH, Eldridge, DJ, Rosentreter, R, Wicklow-Howard, MC, Pellant, M, 2004. Recovery of biological soil crusts following wildfire in Idaho. Rangeland Ecology and Management, 57(1), 89-96.

Hovland, CI, Janis, IL, Kelley, HH, 1953. Communication and persuasion. Yale University Press. New Haven, CT. 315 pp.

Howell, W, 1998. Germination and establishment of Bromus tectorum L. in relation to cation exchange capacity, seedbed, litter, soil cover and water. MS Thesis, Prescott College, AZ.

Jeffries, DL, Klopatek, JM, 1987. Effects of grazing on the vegetation of the blackbrush association. Journal of Range Management, 390-392.

Johansen, JR, 1993. Cryptogamic crusts of semiarid and arid lands of North America. Journal of Phycology, 29(2), 140-147.

Johansen, JR, 2001. Impacts of fire on biological soil crusts. In: Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 385-397.

Johansen, JR, Ashley, J, Rayburn, WR, 1998. Effects of range fire on soil algal crusts in semiarid shrub-steppe of the lower Columbia Basin and their subsequent recovery. Western North American Naturalist, 53(1), 73-88.

Johansen, JR, Javakul, A, Rushforth, SR, 1982. Effects of burning on the algal communities of a high desert soil near Wallsburg, Utah. Journal of Range Management, 598-600.

Johansen, JR, St. Clair, LL, Webb, BL, Nebeker, GT, 1984. Recovery patterns of cryptogamic soil crusts in desert rangelands following fire disturbance. Bryologist, 238-243.

Kleiner, EF, Harper, KT, 1977. Occurrence of four major perennial grasses in relation to edaphic factors in a pristine community. Journal of Range Management, 286-289.

Knapp, CN, Fernandez-Gimenez, ME, 2009. Knowledge in practice: Documenting rancher local knowledge in northwest Colorado. Rangeland Ecology and Management 62, 500-509.

Knapp, PA, 1996. Cheatgrass (Bromus tectorum L) dominance in the Great Basin Desert: History, persistence, and influences to human activities. Global Environmental Change, 6(1), 37-52.

Knutson, KC, Pyke, DA, Wirth, TA, Arkle, RS, Pilliod, DS, Brooks, ML, Chambers, JC, Grace, JB, 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. Journal of Applied Ecology, 51(5), 1414-1424.

Larsen, KD, 1995. Effects of microbiotic crusts on the germination and establishment of three range grasses. Unpubl. Thesis. Boise State University. Boise, ID.

Maestre, FT, Huesca, M, Zaady, E, Bautista, S, Cortina, J, 2002. Infiltration, penetration resistance and microphytic crust composition in contrasted microsites within a Mediterranean semi-arid steppe. Soil Biology and Biochemistry, 34(6), 895-898.

Manning, C, 2009. The psychology of sustainable behavior: Tips for empowering people to take environmentally positive action. Minnesota Pollution Control Agency.

McKinley, DC, Miller-Rushing, AJ, Ballard, HL, Bonney, R, Brown, H, Evans, DM, French, RA, Parrish, JK, Phillips, TB, Ryan, SF, Shanley, LA, 2015. Investing in citizen science can improve natural resource management and environmental protection. Issues in Ecology, 19.

Morgan, JW, 2006. Bryophyte mats inhibit germination of non-native species in burnt temperate native grassland remnants. Biological Invasions, 8(2), 159-168.

Palmer, M, Allan, JD, Meyer, J, Bernhardt, ES, 2007. River restoration in the twenty-first century: data and experiential knowledge to inform future efforts. Restoration Ecology, 15(3), 472-481.

Pechanec, JF, Hull, AC, 1945. Spring Forage lost through cheatgrass fires. Nat. Wool Grower, 35, 13.

Pellant, M, Shaver, P, Pyke, DA, Herrick, JE, 2000. Interpreting indicators of rangeland health. Version 3. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO., 111 pp.

Pellant, M, Shaver, P, Pyke, DA, Herrick, JE, 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO., 122 pp.

Peterson, R, Coppock, DL, 2001. Economics and demographics constrain investment in Utah private grazing lands. Journal of Range Management, 54(2), 106-114.

Pilliod, DS, Welty, JL, 2013. Land treatment digital library. U.S. Geological Survey Data Series 806. http://dx.doi.org/10.3133/ds806 PRISM Climate Group. 2011. Gridded climate.

Pyke, DA, Wirth, TA, Beyers, JL, 2013. Does Seeding After Wildfires in Rangelands Reduce Erosion or Invasive Species? Restoration Ecology, 21(4), 415-421.

Rau, BM, Blank, RR, Chambers, JC, Johnson, DW, 2007. Prescribed fire in a Great Basin sagebrush ecosystem: dynamics of soil extractable nitrogen and phosphorus. Journal of Arid Environments, 71(4), 362-375.

Rau, BM, Chambers, JC, Pyke, DA, Roundy, BA, Schupp, EW, Doescher, P, Caldwell, TG, 2014. Soil resources influence vegetation and response to fire and fire-surrogate treatments in sagebrush-steppe ecosystems. Rangeland Ecology and Management, 67(5), 506-521.

Reynolds, R, Belnap, J, Reheis, M, Lamothe, P, Luiszer, F, 2001. Aeolian dust in Colorado Plateau soils: nutrient inputs and recent change in source. Proceedings of the National Academy of Sciences, 98(13), 7123-7127.

Rogers, EM, 1995. Diffusion of innovations, 4th ed. The Free Press, New York, NY.

Rogers, EM, 2003. Diffusion of innovations, 5th ed. The Free Press. New York, NY.

Serpe, MD, Orm, JM, Barkes, T, Rosentreter, R, 2006. Germination and seed water status of four grasses on moss-dominated biological soil crusts from arid lands. Plant Ecology, 185(1), 163-178.

Shackley, S, Deanwood, R, 2002. Stakeholder perceptions of climate change impacts at the regional scale: implications for the effectiveness of regional and local responses. Journal of Environmental Planning and Management, 45, 381-402.

Skinner, BF, 1953. Science and Human Behavior. Macmillan, New York, New York.

St. Clair, LL, Johansen, JR, 1993. Introduction to the symposium on soil crust communities. Western North American Naturalist, 53(1), 1-4.

St. Clair, LL, Webb, BL, Johansen, JR, Nebeker, GT, 1984. Cryptogamic soil crusts: enhancement of seedling establishment in disturbed and undisturbed areas. Reclamation and Revegetation Research, 3.

Tongway, D, Hindley, N, 2000. Assessing and monitoring desertification with soil indicators. In: Rangeland desertification. Springer Netherlands, pp 89-98.

United States Department of Agriculture (USDA) and United States Department of the Interior (USDI), 2003. Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy. 57 p. Available: http://www.nwcg.gov/branches/ppm/fpc/archives/fire_policy/index.htm (Accessed 15 March 2017).

United States Forest Service (USFS), Rocky Mountain Research Station (RMRS), 2004. Fuels planning: science synthesis and integration; forest structure and fire hazard fact sheet 05: fuel treatment principles for complex landscapes. Res. Note RMRS-RN-22-5-WWW. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2 p.

USFS, 2012. National Best Management Practices for Water Quality Management on National Forest System Lands Volume 1: National Core BMP Technical Guide. FS-990a. Available at: http://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf (Accessed 15 March 2017).

US Government Accountability Office (GAO), 2003. Wildland fires. GAO-03-430.

US GAO, 2006. Wildland fire rehabilitation and restoration. GAO-06-670.

Walker, B, Salt, D, 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Washington, DC, USA: Island Press. 174 pp.

Warren, SD, St. Clair, LL, Johansen, JR, Kugrens, P, Baggett, LS, Bird, BJ, 2015. Biological Soil Crust Response to Late Season Prescribed Fire in a Great Basin Juniper Woodland. Rangeland Ecology and Management, 68(3), 241–247. http://doi.org/10.1016/j.rama.2015.03.007 (Accessed 15 March 2017).

Weick, KE, Sutcliffe, KM, 2011. Managing the unexpected: Resilient performance in an age of uncertainty (Vol. 8). John Wiley & Sons.

West, NE, 1990. Structure and function of microphytic soil crusts in wildland ecosystems of arid and semi-arid regions. Advances in Ecological Research, 20, 179-223.

Whisenant, SG, 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, ED, Romney EM, Smith SD, Tueller, PT, (compilers). Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 4-10.

Wright, V, 2010. Influences to the success of fire science delivery: perspectives of potential fire/fuels science users. USDA Forest Service, Rocky Mountain Research Station, Final Report to the Joint Fire Science Program, JFSP Project, pp.04-4.

CHAPTER 2

A SOCIAL-ECOLOGICAL SYSTEMS APPROACH TO POST-WILDFIRE RESTORATIONS IN THE GREAT BASIN AND MOJAVE DESERT: LAND MANAGER AND LOCAL CITIZEN VALUES

Abstract

Following a wildfire, land management agencies act quickly to protect ecosystem services. On-the-ground decisions are both complex and made under tight deadlines, during which managers must address a system's ecological and social-political variables. We don't currently understand how post-wildfire managers make coarse- or fine-scale trade-off decisions in the Great Basin, or if these decisions reflect the best indicators of ecosystem health according to current science. Translational ecology seeks to bridge communication barriers between researchers, stakeholders, and managers. I used a translational framework to provide information about time-constrained post-wildfire scenarios. In this chapter I evaluated manager perceptions of stakeholder values and public values to learn how/if these values influence land management decisions. Manager perceptions were measured through semi-structured phone interviews (n = 8) and a structured online survey (n = 256). Public surveys were mailed to 1,000 (971 deliverable, n = 152 usable) residents in rural and urban Great Basin and Mojave Desert ZIP codes. Using Brunson's (2014) multi-scalar model, we found coarse- and fine-scale social, political, and ecological variables were associated with post-wildfire management decisions, even for unique management cultures bounded by policy. The specific variables identified can be used as a guide for agencies wanting to engage local public.

Social-political variables should be considered in ecological modeling efforts that assess past restoration success as well as those attempting to establish restoration site prioritization.

Keywords: Wildfire, Social-ecological systems, Restoration, Land managers

Introduction

While agency policy asks managers to use “best practices,” interpretation of what those practices are remains context-dependent in semi-arid rangelands. Managed ecosystems are, by definition, social-ecological systems, or SES (Walker et al. 2004; Brunson 2012, 2014). Encouraging restorations that promote connectivity across socio-political borders (a factor of significant ecosystem importance) requires an understanding of social-political-ecological contexts, all of which vary spatially and temporally. Though often overlooked historically, stakeholder knowledge, preferences, and goals can have a significant impact on management success and may help reduce uncertainty in management decisions (Peterson and Coppock 2001; Knapp and Fernandez-Gimenez 2009; Hallett et al. 2013).

Land manager decisions are largely shaped by agency policy and institutional cultural norms (Weick and Sutcliffe 2011). However, the context-dependent nature of ecological restorations requires some flexibility in on-the-ground management decisions. Context dependence is equally true for the social-political characteristics of each project. The research in this chapter explored the relative strength of different options managers are able to “trade” within the bounds of policy and social pressures (e.g., for the same cost, does a manager choose the better seeding tool or treating the most acres). Trade-off decisions were couched within the concept of coarse- and fine-scale factors (Brunson 2014, see Fig. 2.1) and tested with structured surveys. Coarse-scale variables refer to those social, political, and ecological variables that occur outside of the landscape level (e.g., national policy), while fine-scale variables occur within the landscape (e.g., local stakeholders).

The Theory of Planned Behavior (Ajzen 1991) suggests attitudes about a behavior influence the likelihood that the particular behavior will occur. Attitudes are developed through subjective norms, perceptions of behavioral control, self-efficacy,

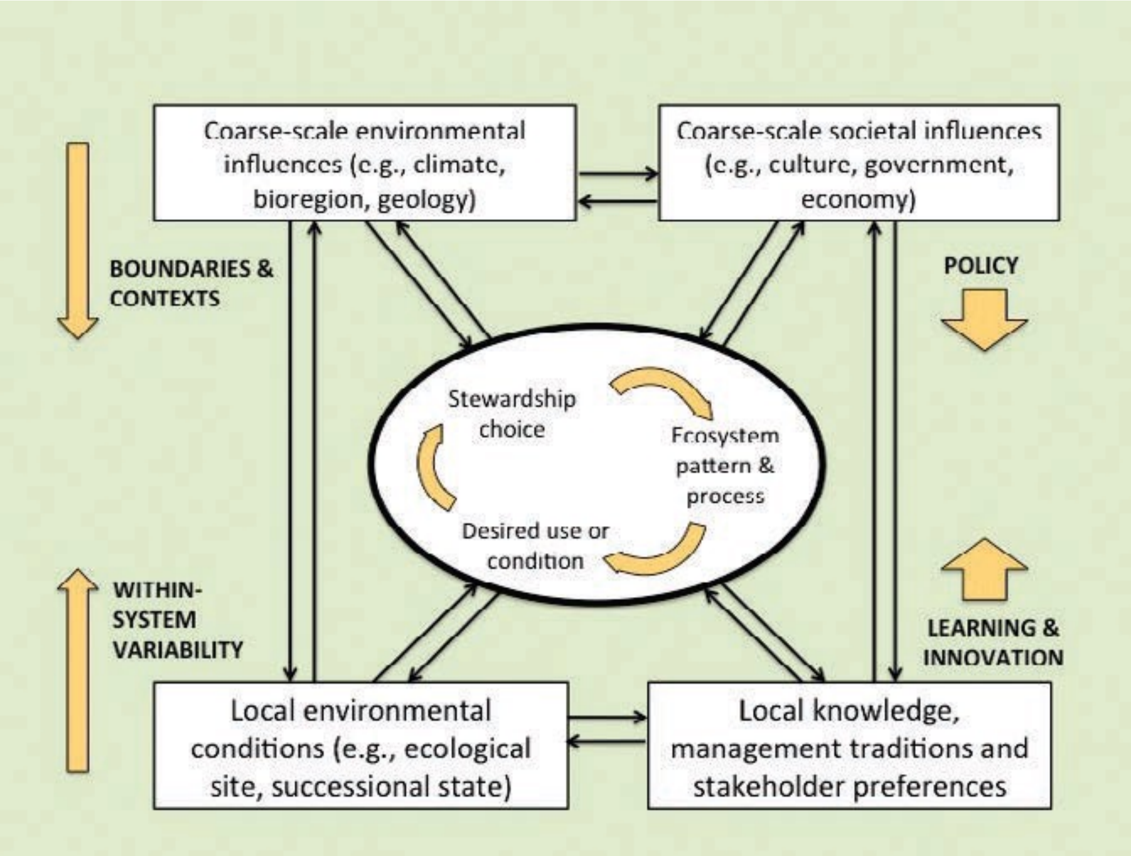

Coarse-scale environmental influences (e.g., climate, bioregion, geology)
Coarse-scale societal influences (e.g., culture, government, economy)
BOUNDARIES & CONTEXTS
POLICY
Stewardship choice
Ecosystem pattern & process
Desired use or condition
WITHIN-SYSTEM VARIABILITY
LEARNING & INNOVATION
Local environmental conditions (e.g., ecological site, successional state)
Local knowledge, management traditions and stakeholder preferences

Fig. 2.1. Multi-scalar model. This research attempts to fill communication gaps in post-wildfire projects using a multi-scalar model of social-ecological systems (Brunson 2014). In this model coarse- and fine-scale social-political and ecological variables create iterative feedbacks on decision making and ecosystem patterns.

(ability/infrastructure/support to achieve an action), and beliefs that important others will find the action desirable. In a land management context, behavioral control may relate to both political processes and promotional considerations. Land managers, while also bounded and influenced by institutional norms, may, over time, be subject to “capture,” defined by Culhane (2013) as a shift in subjective norms from association with a particular *homogenous* culture or community for a long, or important/influential time (e.g., during disasters). However, Culhane (2013) also argues that very few if any land managers are exposed to homogenous interests any longer; additionally increased professionalism of land management agencies is able to bolster against negative capture, and local interest may even support professionalism. He suggests field-level managers are more subjected to “group influence” (p 332); herein is where our interest lies.

A Translational Ecology framework (described below) expands upon Innovation Adoption (Chapter 3) by accounting for communication that focuses on iterative and adaptive learning processes (Brunson and Baker 2015). Translational collaborations appear to increase trust and encourage social resilience to social, political, and environmental disturbances (Daniels and Walker 1996; Walker and Salt 2006; Cabin 2007; Palmer et al. 2007; Manning 2009; Coppock et al. 2015; McKinley et al. 2015). While translational and other SES collaborations are gaining recognition in facilitating restoration success, ecosystem connectivity, and long-term public stewardship, institutional capacity for post-wildfire translational projects will likely remain elusive for current and foreseeable future projects. Thus, translational concepts were applied to surveys using a social-ecological systems multi-scalar model (Brunson 2012, 2014); this model may help fill gaps in understanding and communication between post-wildfire public land managers, researchers, and stakeholders (Figure 2.1 from Brunson 2014).

Translational Ecology

Translational ecology surmises that effective applied research and innovation can only occur with transparency and communication of attitudes, beliefs, and intentions from managers, researchers, and stakeholders (Schlesinger 2010). Otherwise information flow stagnates, attitudes and beliefs are misinterpreted, and intentions may unnecessarily vary. Research may end up at cross-purposes with what managers or stakeholders want. Post-fire rehabilitation practices may seem incongruent with best-practices to stakeholders. Translational ecology provides an approach that may bridge these concerns more effectively than the often-begrudged NEPA (National Environmental Policy Act) process. The NEPA process is typically the only formal way members of the public can comment on restoration projects; yet post-wildfire projects are often warranted categorical exclusions. Consequently, we don't really know what local communities think about the majority of post-wildfire land management decisions. The research presented herein acts as a proxy for non-translational post-wildfire projects. We ask: do manager and public/taxpayer values align? Does policy support intention? These are basic questions that research and logic suggest are critical to long-term restoration success.

Encouraging different types of stewardship can increase the social resilience of ecosystems (Walker and Salt 2006; Coppock et al. 2015; McKinley et al. 2015). Adger (2000, p. 347) defines social resilience as the ability of communities to resist or rebound from external stressors (social, political, *or* environmental). This differs from ecological resilience in that communities and institutions actively choose pathways. Several papers have called for increased monitoring of projects as well as follow-up or tiered projects (Wirth and Pyke 2007; Knutson et al. 2009 and 2014; Pyke et al. 2013). Agencies have responded to these calls. Monitoring guidelines were added to the Bureau of Land Management's Emergency Stabilization and Rehabilitation handbook in 2005 (Pellant et al. 2005). Additionally, funding allowing for post-wildfire monitoring and successive treatments was recently extended from 3 years to 5 years; however as this amendment only applies "when extenuating circumstances can be demonstrated" (DOI 2016), region-wide monitoring efforts are likely to remain short-term in the near future. Additionally, whether 5 years is sufficient to assess ecosystem health remains to be seen. With and regardless of this uncertainty, it seems only strategic to increase resilience by building social networks that can work collaboratively to respond to wildfire affected lands (Walker and Salt 2006).

Social resilience necessitates trust and communication between land management agencies, local citizens, and interest groups. Examples of effective translational restoration approaches are beginning to emerge. Collaborations and citizen science efforts help alleviate subjective norms as well as strengthen trust, increase self-efficacy, and increase positive experiences with land agencies (Fernandez-Gimenez et al. 2008; Lister et al. 2012; Toledo et al. 2012; Toledo et al. 2013; McKinley et al. 2015). Trust has been a historically unwieldy barrier in land management; it is hard to gain and easy to lose. Procedural justice literature suggests key components to building trust are perceived fairness in the process and being heard (Lawrence et al. 1997). In post-wildfire scenarios, NEPA categorical exemptions may bypass these needs entirely. Collaborative partnerships increase cooperation across ecologically relevant scales that exceed political boundaries (Toledo et al. 2014); in conjunction with NEPA collaborative partnerships may bolster the social-ecological resilience of post-wildfire systems.

Manager and Stakeholder Opinion Literature

Research surrounding land manager beliefs and attitudes about project effectiveness must start with an understanding of land managerial culture. Managers are considered to work in a unique professional culture (Kennedy 1985) built around commodity-oriented policy implemented prior to the 1960s and moderated by environmental protection oriented policy implemented after 1964 (Sayre 2010). Today's policy reflects ecosystem-based sustainability and resilience theories. In the past, managers' beliefs have been partially shaped by prevailing opinions in the local community (Kennedy 1985; Kennedy et al. 2001). However, policy may be seemingly at odds (in the short-term) with the local communities that depend on rangelands for their livelihood (Cramer et al. 1993; Kennedy et al. 2001). While the NEPA process requires public hearings and public comments, these processes tend to elicit negative feedback, may cause misinterpretation of broader public beliefs, and rarely facilitate further discourse or education (Moote et al. 1997). Collectively this culture and belief system seems to predispose managers to think their decisions are unpopular. Indeed, several studies have shown manager perception of public and stakeholder opinions may be inaccurately negative (Vining and Ebreo 1991; Nardi 2009; Rieber 2011; Nardi 2012; Barry 2014). However, several studies have found the general public to be both sophisticated in their understanding of ecological processes and risk, and supportive of innovative restoration plans (Vining and Ebreo 1991; McCaffrey and Olsen 2012). This seems to suggest managers may misinterpret the interested public and highlight methods in conjunction with the NEPA process are needed to bridge these communication gaps.

Public attitudes about wildfire influence how it is managed and can therefore have large impacts on local ecology (DellaSala et al. 2004). Understanding public and interest group values allows agencies and managers to better establish policies and goals and more easily mitigate potential conflicts (Machlis 2002; Tarrant et al. 2003: 26). Ignoring what public or stakeholders want undermines agency goals, increases tension, and may lead to long-term project failure (Shindler et al. 2002). Consequently, the Forest Service now provides guidelines for managers specifically addressing public and stakeholder values, beliefs, and attitudes (Allen et al. 2009) and recommending studies such as this one.

Over the past decade, several studies have addressed the question of how the public perceives the outcomes of wildfire prevention such as prescribed fires and/or mechanical thinning (e.g., Vogt et al. 2005; Carroll and Bright 2009). Public attitudes toward wildfire have also been well studied, thanks in large part to the formations of the Joint Fire Science Program and National Fire Plan (1998 and 2000 respectively). In association with these programs, McCaffrey et al. 2013 performed meta-analyses that included 64 articles on public acceptance of fire and fuels management and 30 articles on public perceptions of wildfire risk. In general local public supported thinning and even prescribed fire on high-risk public lands (especially those further from Wildland-Urban Interfaces). Familiarity with treatment and trust in agencies were important predictors. This conflicts with the generally accepted viewpoint that local communities are unwilling to accept prescribed fire (although distance was found to be an important covariate). Previous experiences with wildfire and traditional (non-collaborative) experiences with land management agencies were also likely to magnify fears of negative consequences (Bright et al. 2007). Overall, treatment risk perceptions were complex; those with prior wildfire experience both had greater and lowered risk perceptions (Winter and Fried 2000; McCaffrey 2004; Blanchard and Ryan 2007; Flint 2007; Cohn et al. 2008). These studies primarily focused on fire prevention strategies, while we are interested in public perceptions of post-wildfire restorations.

Understanding how citizens perceive fire and specific fuel treatments is essential to land managers' success in negotiating mutually acceptable fire management plans (Brunson and Shindler 2004; Kneeshaw et al. 2004a; Kneeshaw et al. 2004b, Allen et al. 2009). Trusting those responsible for managing technology, especially in situations with a high hazard potential, is an important explanatory factor for support of resource management policies (Vaske et al. 2008). Community engagement has been shown to alleviate some aspects of "wicked problems" by resolving ecological dissonance (Clewell and Aronson 2006), improving agency relationships (Ryan and Hamin 2008), and providing many social and ecological benefits (Grese et al. 2000). Unidirectional flows of information (e.g., education) often result in frustration, weak public support, and implementation barriers (Moote et al. 1997; Rowe and Frewer 2000; Renn et al. 1995; Germain et al. 2001). However, collaborative projects require inputs in time and commitment from managers, stakeholders, and public. Post-wildfire time frames do not currently support this type of collaboration. Therefore, we used Brunson's (2012, 2014) multi-scalar model to identify and explore translational information gaps that may enhance social and ecological resilience in post-wildfire restoration projects.

As a substitution for a translational approach, the research presented herein explores coarse- and fine-scale social-political, and ecological factors (Brunson 2012, 2014) influencing post-wildfire restoration projects. In this chapter we asked: what do managers and the public think of post-wildfire projects, which factors (social, ecological, political) do managers most value? Do manager and public/taxpayer attitudes align? Do managers feel policy supports post-wildfire considerations? In addition to these basic questions, we hypothesized wildfire and climate risk variables, coarse- and fine-scale social norm perceptions (community and interest group opinions) and would be associated with manager values and decisions.

Methods

Semi-structured Interviews

A semi-structured interview protocol was used to assess the types of questions that would be most relevant to a broader management community (Appendix A). The interview protocol was designed as a flexible guide that could elicit responses with a basic level of conformity (Creswell 2009). Interviews were not intended to describe all post-wildfire land managers in the Great Basin. The goal was for respondents to express their professional perceptions or concerns about post-wildfire decision-making.

Managers were identified by job title and field office (1,624 potential post-wildfire managers). Agencies included the Bureau of Land Management (BLM), Forest Service (FS), Fish and Wildlife Service (FWS), and National Park Service (NPS). A random selection routine in the statistical software package R (2015) was used to obtain two numbers from each 100 managers, between 1 and 1,624 (e.g., 2 from 1-100, 2 from 101-200, etc.). Thus 32 managers were contacted via email in January of 2012 for participation with our semi-structured interviews. If a manager declined to participate, their name was replaced with a new randomly derived participant. Ultimately 55 managers were contacted for participation and eight interviews were completed.

Each interview lasted 30 minutes to 1 hour. Eventually in a semi-structured interview process, patterns emerge and no new information is forthcoming – the process is said to be "saturated" (Glaser and Strauss 1967). Further interviews become unnecessary, as these patterns will be more rigorously tested with structured surveys. After eight interviews were completed, enough information had been elicited to proceed with the structured survey design.

To prevent biased or leading questions, formal hypotheses were not developed prior to the interview process (Glaser and Strauss 1967). However, the interview protocol did include some context-specific characteristics found in previous studies as potentially predictive. For example, an earlier study found tenure at a position may influence some managers' perceptions of local climate changes (Whitcomb 2011). Thus, we hypothesized tenure may likewise influence certain aspects of post-wildfire restorations. The protocol addressed respondents' general restoration procedures, notable social and ecological factors that affect their process, and typical trade-off decisions they might make.

Qualitative data are typically lengthy and somewhat unorganized (Huberman and Miles 1983). Data reduction techniques that code responses into categories and major themes allow data to become more interpretable. Qualitative analysis is inherently subjective and requires rigorous and careful consideration of alternative interpretations (Yin 1994). Qualitative data are intended as exploratory research—as such, if an interpretation is compelling or controversial, it can be further tested as a hypothesis in a structured formal survey.

Structured Survey – Post-wildfire Managers

Results from semi-structured interviews (Tables 2.1–2.3) were used in conjunction with previous literature to construct a structured survey instrument (Appendix B). The survey was divided into 4 general sections each addressing coarse- and fine-scale attributes: social characteristics (general, job, wildfire), policy context (time-frame and funding constraints), stakeholder perceptions alignment (opinions, trade-off decisions, and public concerns), and ecological study results (research partners' results). This last section is beyond the context of this chapter and will be discussed in Chapter 4.

Three characteristics were included due to their common predictive capacity in surveys: age, gender, and education. Region was separated into three categories: Great Basin, Mojave Desert, and Southern Great Basin. Brussard et al. (1998) summarize the complexity of the transition zone between the Great Basin and Mojave Desert, and differences in flora and fauna. We hypothesized variables in our survey might represent different trade-offs for Southern Great Basin managers compared to either of the other regions. Using the transition zone Brussard et al. identified (115 kilometers wide, and encompassing shifts in dominant floristics, elevation, temperature, and precipitation from

Table 2.1
Semi-structured interview results, social-political variables. Which have the greatest influence on post-wildfire decisions identified by interviewees?

Not enough long-term (past 3 years) funding	6
Political pressure	5
Primary stakeholders agree with restoration decisions	5
Local/regional public are concerned about post-wildfire restorations	4
Time-constraints (7-21 days to submit proposals)	3

Table 2.2
Semi-structured interview results, ecological variables. Which have the greatest influence on post-wildfire restorations identified by interviewees?

Non-natives useful	5
Short term weather; seed choice	5
Short term weather; timing	4
Seed cost / availability	4
Soil loss	3
Hydrology	2

Table 2.3
Semi-structured interview results, new science incorporation. Opinions regarding ecological variables science suggest have an influence on post-wildfire landscapes

Biological soil crusts are not considered	6
Dust is not an issue	5
Long term climate too complex to be realistically considered	5

rain to snow), field office summaries supplied by agency websites, and Google Earth (Map data ©2016 Google), we identified which field offices could be reasonably categorized as Southern Great Basin transition zones.

Personal risk experiences and/or perceptions (e.g., past exposure to wildfire or flooding) have been found to influence manager decisions (Shackley and Deanwood 2002). Living in specific communities longer increases exposure to local norms (cf. Norm Theory, Capture Theory). While "capture" by local interests has often been viewed as something to avoid (Culhane 2013) the importance of local ecological knowledge for social and ecological resilience is increasingly acknowledged (Fernandez-Gimenez et al. 2008). To avoid possible negative connotations of "capture", collectively, this category of predictors will be referred to as place "exposure". Local community respondents also vary in their risk perceptions (wildfire, climate, and ecosystem) and place "exposure" (residency length, recreation frequency); these variations may influence public attitudes regarding post-wildfire projects.

Institutional policy, while critical to the institution and legal parameters of their missions, can also be perceived as major barriers to on-the-ground decision making needs (Cortner et al. 1998). In the semi-structured interviews used to develop structured surveys, land managers discussed two pervasive institutional barriers in post-wildfire landscapes: time-frames for assessing the landscape post-wildfire and funding limitations (competition and long-term funding). Managers expressed concern that even if they successfully compete for the limited funds available (much of which may depend on what time of year the fire strikes) the funding time-frames (at the time of the survey 2-3 years) were just not ecologically realistic. As one manager said, "The biggest short-coming in

ESR (Emergency Stabilization and Rehabilitation) is the funding time is too short, especially in the Mojave Desert. Even in the Great Basin, you'd be lucky to see a response in 3 years. More like 5 years before you *might* see a response." Another commented that "the bigger the fire, the less realistic the time frame is." Recently, land management agencies have responded to this common concern by lengthening monitoring and subsequent treatment response post-project to 5 years, when "needed" (DOI 2016). It remains to be seen if managers, researchers, and stakeholders find this to be sufficient, or how/if this affects funding for other proposal components.

The third section of the survey was based on how managers evaluate ecological trade-off decisions, especially with regard to their social and political perceptions. A majority of managers interviewed (5 of 8) at some point experienced outside political or social pressure regarding their post-wildfire decisions. As one manager said, "Tradeoffs can also be political, and sometimes we have to seed an area that we don't think even needs it". Similarly, another manager expressed concern regarding the disparity of public perception and the need for restoration: "[We are] less aggressive in how we treat because of the public's lack of understanding of process. A lot of special interest groups don't recognize the need for hands-on restoration—they want it all to come back naturally." Finally, interest group policy pressure concerning the perceived ecological costs of grazing, were seen by some managers as ecologically neglectful: "If we'd been able to graze it, the fire never would have happened. But there is just so much standing litigation, we can't move forward." This section had a two-fold design: to test manager congruency with public and stakeholder opinions about post-wildfire decisions, and to assess realistic social/political/ecological trade-offs managers might experience.

The structured manager survey was administered to land managers throughout the Great Basin and Mojave Desert using SurveyMonkey, Inc., an online survey tool. All 1,624 managers identified were emailed a letter of information and the questionnaire in February 2013. Active emails were confirmed by the software and questionnaires were delivered to 1,490 individuals. Two reminder emails were sent and the survey was kept open until May 1st.

Structured Survey – Local Citizens

A structured paper survey was mailed to 1,000 residents of the Great Basin and Mojave Desert (Appendix C). ZIP codes in the Great Basin and Mojave Desert were identified and given to Survey Sampling International (SSI®). SSI® provided 1,000 randomly derived mailing addresses from within the ZIP codes. Following Dillman's design (2007) for maximizing survey response, postcards were sent in May 2013 to the mailing addresses, requesting participation in the study, noting university sponsorship, and providing follow-up contacts. All of these traits have been shown to increase response rates (Heberlein and Baumgartner 1978; Fox et al. 1988). Postcards were followed one week later by a more in-depth information letter, the survey itself, and a postage-paid return envelope. Another postcard was sent 10 days later thanking those who had participated and encouraging non-respondents that their participation was essential. This was followed 10 days later by one final round of information letters, surveys, and return envelopes sent only to those participants who had not yet responded (n = 918).

Public surveys were designed to mirror manager surveys as much as possible. The first section measured respondent characteristics, including more specific recreation questions (type and frequency). Some studies have found different types of recreation can be associated with different ecological preferences (Jackson 1986; Larson et al. 2011). We hypothesized different recreation types may also be associated with post-wildfire restoration attitudes. Wildfire and climate risks were assessed with the same questions as the manager structured survey. Trade-off decisions, general policy questions, local interest, and larger public interest questions were also identical. Public surveys included questions regarding the survey-takers' previous interest regarding post-wildfire restorations as well as trust in agencies and support of common restoration techniques. Several questions assessed public respondents concerns about public lands both in general and post-wildfire situations (e.g., invasive grasses, smoke, etc.).

Analysis

The semi-structured interview answers were coded and prevalent themes were summarized following recommendation by Yin 1994 (Tables 2.1:2.3). Structured interview results were explored in R (2015. Frequency tables were created and Pearson's Chi-squared test for given probabilities were performed for every question and every 2-way combination of questions in the structured manager survey. Repeated random forest classification trees were then run on each 'response' variable (e.g., age or gender are considered predictors of the response 'time frame adequacy') using the Boruta package (Miron et al. 2010) in R. This package repeats random forests classification trees up to 498 times and took anywhere from < 1 minute to 10 minutes to run for any given model in this dataset. Because successive trees do not depend on earlier trees, and sampling is random each time, repeated random forest analysis generates fewer false positives than parametric techniques, and increases accuracy of the binary decision split (i.e., node purity, Breiman and Cutler 2007). In principle, when strong interactions are likely to be present, random forest decision trees should outperform linear regression methods (Cutler et al. 2007). At each node, the number of predictors available are restricted; this ensures correlations are small. Classification trees do not compute traditional statistical results (p values, coefficients, or confidence intervals)—they are used for classification of important variables.

Two-way cross-tables were created using important variables identified through Boruta and significant variables identified through Chi-square analysis. Pearson's Chi-squared test for given probabilities were performed to test the independence of the column and row variables. By default, the p-value is computed from the asymptotic chi-squared distribution of the test statistic (with continuity correction when 2-by-2). However, if an error arose (e.g., small expected cell counts), a Monte Carlo simulation test was used with 2000 replicates.

Land managers may feel compelled to make certain decisions based on their perception of general population opinions and values (norm activation, risk of political action). For example, one interviewee observed: "[The public is] always interested in fires when they are burning, but they don't care when they are over. [They are] not interested in rehabilitation—which is important when the sites are undergoing a conversion back in those same landscapes every year." It is important to understand what the taxpayer actually values for these post-wildfire landscapes. The public survey was coded and then analyzed using the same methods as the manager structured survey.

Results

Semi-structured interviews were continued until saturation was reached (*n* = 8). There is no statistical test for saturation; in this qualitative arena, saturation is a subjective measure based on the researcher. Saturation is reached when themes have emerged and no new information is forthcoming. In other words, enough data is received to build hypotheses for more rigorous testing (Yin 1994). Long-term monitoring and social-political involvement were often mentioned as major influencers of post-wildfire decisions (Table 2.1). Weather and seed choice were the most mentioned ecological considerations (Table 2.2). Science results were most likely to be considered unrealistic for incorporation into actual restoration plans (Table 2.3).

We used general demographic information, job characteristics, wildfire risk, climate change risk, and perceptions of public values to predict manager and public opinions about policy, science, and project effectiveness. Structured online surveys were sent to 1490 land managers with potentially related job titles; from these 256 completed the survey (17% response rate, although this is likely much higher when considering irrelevant job titles contacted). Public structured surveys were sent to 1000 rural and urban residents in the Mojave Desert and Great Basin, 971 of which were deliverable; 152 usable surveys were received, 16% response rate. While this is a low overall response rate, more directly affected rural residents returned a 23% response rate and urban residents 9%. Post-fire restoration practices are a specialized topic. Those public that responded are most likely to be affected by practices and/or participate in public involvement activities or campaigns; thus, while overall response rate was low, the views elicited in this survey remain relevant.

Characteristics: Who Took Our Survey?

Nearly 60% of managers were 40-59 years old, while just 6% were older than 60; public survey respondents were older than manager respondents (54% > 60). The majority of managers and public respondents were men (> 70%) living in rural communities for over 15 years. Public respondents were more likely to live on smaller properties (< 1 acre) that they own. Manager respondents reflected public land agency responsibility: the majority of respondents work for the BLM (77%) and in the Great Basin (67%) and were relatively evenly distributed among states. Most manager and public respondents experienced fire near their home < 5 years ago (> 60%) and live close to areas that might burn (> 80% within < 1-5 miles). The overwhelming majority (93% managers, 72% public) felt risk of a wildfire near their personal residence in the near future was 'likely' or 'very likely.'

On non-work related time, 70% and 78% of managers recreate at least monthly in state/national parks and multiple-use rangelands respectively. Public respondents recreated much less frequently than managers and were less likely to recreate in parks than on rangelands (18% and 38% at least monthly); over half of public recreated at least yearly. Public surveys also asked which activities respondents engaged in. Most common activities were hiking, fishing, camping, and off-highway vehicle recreation (40-60%). Majority of respondents did not ride horses, hunt, or backpack often or ever (70-80%).

Public respondents were also asked to rate their concern regarding general and post-wildfire ecosystem risks. Seventy-four percent were concerned about invasive grasses (vs. 9% not), and 57% expressed concern about invasive forbs (vs. 15%). Public overall were least concerned about tree encroachment (25 vs. 46%). Regarding wildfire-specific risks, public respondents were most concerned about wildlife and fish habitat, loss of forage, risk to human safety/health, and increased soil erosion (Table 2.4). They were the least concerned about driving and recreation. It is important to note that while public still indicated some post-wildfire concern about invasive plants, these factors were not as important as other factors in overall public assessment of post-wildfire concerns.

Social Engagement

Semi-structured interviews suggested social and political pressures were important considerations associated with manager decisions. In the structured survey, we asked managers and public how much social and political involvement they perceived in post-wildfire projects (Table 2.5). Most managers felt local communities and interest groups are concerned about post-wildfire projects, and the local community agrees with their decisions (Table 2.5). Local public concern was significantly related to both larger public and interest group concern (X-squared = 163, df = 9, p-value < 2.2e-16; X-squared = 156, df = 9, p-value < 2.2e-16). In other words, when locals are concerned, interest groups are often also concerned, and managers face both social and political pressures. Members of the public were less likely to think local communities are concerned about projects and more likely to think they agree with post-wildfire project decisions.

Table 2.4
Public survey: Fire-related concerns. *Please indicate how concerned you are about the following possible effects from a wildfire*. Left column ranks most likely.

Most concerned Very/Total	Possible fire effects	Very concerned	Total concern very + slightly	Neutral	Not concerned
2/2	**Risk to human safety/health**	**64%**	**91%**	5%	4%
-/4	Increased smoke	45%	84%	7%	9%
	Hazard to driving	28%	68%	13%	19%
4/5	Deteriorated public water supply	56%	83%	10%	8%
3/3	**Increased soil erosion**	**57%**	**90%**	7%	3%
5/1	**Loss of forage**	**54%**	**93%**	5%	2%
1/1	**Loss of wildlife and fish habitat**	**67%**	**93%**	6%	1%
-/5	Increase in invasive grasses	45%	83%	14%	3%
	Increase in invasive wildflowers	34%	75%	17%	8%
	Effects on recreation activities	26%	68%	19%	13%
	Reduced scenic quality	35%	73%	18%	9%

In the public survey, those that identified as concerned prior to the survey tended to be more actively involved in their local landscapes (both outdoor recreation and socially) and were most concerned about invasive species (Table 2.6a). They were also more likely to think agencies are effective and policy is realistic. Managers that felt local communities agree with their decisions were less likely to perceive local and interest

Table 2.5

Public and manager surveys: Post-wildfire project concern

		Disagree	Neutral	Agree	Don't Know
1) The local community is not concerned about post-wildfire projects in my area	Manager Public	75% 25%	11% 17%	12% 46%	3% 12%
2) Before this survey, I (Public respondent) was not concerned about post-wildfire projects	Public	51%	28%	15%	5%
3) The larger public is not concerned about post-wildfire projects in my area	Manager Public	38% 8%	6% 15%	36% 64%	6% 12%
4) Outside interest groups are not concerned about post-wildfire projects in my area	Manager	68%	13%	12%	7%
5) The local community agrees with the majority of post-wildfire treatment decisions	Manager Public	20% 8%	28% 33%	40% 30%	11% 29%

Table 2.6a

Public survey: Concern about projects before this survey. *Before this survey I was concerned about post-wildfire projects:* (N = 144, 95%). All identified in Boruta – see Appendix C, Q. 26, for all significant correlations.

Variable	Chi-squared	DF	p-value
More frequent backpacking	12.993	6	0.04314
More frequent horse riding	16.377	6	0.01187
More frequent hunting	20.746	9	0.01383
More frequent state and national parks recreation	18.84	9	0.02658
More frequent multiple-use rangelands recreation	53.794	12	2.974e-07
Larger properties[1]	5.0858	6	0.5329*
Concerned about tree encroachment	8.0679	3	0.04463
Concerned about invasive forbs	16.611	6	0.01083
Concerned about invasive grasses	12.508	6	0.05154
General policy is realistic	46.448	9	4.973e-07
Local communities are concerned	70.31	9	1.324e-11
Drilling is more effective than aerial seeding	28.398	9	0.0008182
Agencies are effective at stabilizing soils	23.867	9	0.004517

[1] not significant but identified in boruta: 77% of respondents with properties > 10 acres were concerned before the survey vs. ~ 50% of respondents with properties < 10 acres.

Table 2.6b
Manager survey: Local community agrees with decisions. *The local community agrees with the majority of post-wildfire treatment decisions*: (*N* = 225, 88%).

Variable	Chi-squared	DF	p-value
Younger than 60*	18.596	6	0.005
Work primarily in the office*	14.907	6	0.021
Sites may be able to naturally heal*	20.224	6	0.003
Shifts in temperatures are not a local concern*	25.727	9	0.002
BSC assessments are not needed*	23.812	9	0.005
Fertile islands do not need to be accommodated*	29.368	15	0.014
Krat presence does not require increasing seed*	20.659	12	0.056
Locals are not concerned about post-wildfire projects	53.016	9	2.903e-08
IGs[1] are not concerned about post-wildfire projects	62.697	6	4.039e-10
Time frames are adequate for proposal submission	16.302	9	0.061
Proposal time frames rarely cause changes to projects	12.908	6	0.045
Lack of funding rarely causes changes to projects	12.202	6	0.058
Policy should be followed precisely	21.505	6	0.001
Policy is realistic	26.975	9	0.001
Droughts and floods are not a concern	22.649	9	0.007
Not concerned about Halogeton abundance	15.359	9	0.082

*Boruta identified [1]IG = interest group

group concern and more likely to think time frames, funding, and policy are reasonable; they were also typically less concerned regarding environmental variables (Table 2.6b). Managers tended to believe public and interest groups hold opposite preferences to themselves (Table 2.7a; also see Tables 2.11 – 2.15).

Some manager ecological opinions did seem to be associated with community post-wildfire interest and perceived preferences (Table 2.7a), but were unlikely to be associated with perceived public opinions (Table 2.7b). Associations were most likely to be related to local climate concerns and seed preference. Of note, when members of the public were concerned about projects and agreed with management, managers were more

Table 2.7a

Manager survey: Local norms (invested) and manager decisions. ***Bold*** **=** significant**.** DK=Don’t Know.

	Perceived public post-wildfire project concern and opinions		
Manager preferences	Local community concern: post-wildfire projects	Larger public concern: post-wildfire projects	Local community agrees w/post-wildfire decisions
1) Projects are crucial to site rehabilitation / sites can naturally heal	***Public concern: DK/Neutral, Managers = naturally heal***	No effect	***Locals agree: DK Managers: naturally heal***
2) Projects should be science-based / science often doesn’t fit ecosystems	No effect	***Larger public: Neutral Managers: Science***	***Science***
3) Prioritize visibility / more severe post-wildfire ecosystem effects	Visibility[1]	No effect	***Visibility***
4) Prioritize livestock / higher densities of invasive annual grasses	No effect	No effect	No effect
5) Prefer native species only / non-natives are acceptable	***Non-natives***	No effect	***Locals agree: non-natives. DK/Neutral: natives***
6) Prefer to treat more acres / increase monitoring length	No effect	No effect	No effect
7) Prioritize sites with more political pressure / more severe post-wildfire ecosystem effects	Political[2]	No effect	Severity[2]
8) Prefer to treat more acres / use the best tools	No effect	No effect	No effect
9) Droughts and/or floods are a danger to local ecosystems	No effect	***Not a concern***	No effect
10) Long-term shifts in local temperatures are a danger to local ecosystems	***Not a concern***	***Are a concern/neutral***	No effect

[1] N too low for reliable statistics; however, of the managers selecting visibility, none felt locals are not concerned.

[2] N too low for reliable statistics; however, of the managers selecting political sites, most felt locals are concerned and none felt locals disagree with decisions - none chose political sites when locals are not concerned.

Table 2.7b

Manager survey: Local norms (local opinions) and manager decisions. ***Bold*** = significant. DK=Don't Know. ne = neutral.

	Perceived public post-wildfire opinions/preferences		
Management preferences	Public want projects to follow policy precisely	Public prefer science-based projects	Public think projects are crucial to site rehabilitation
1) Projects are crucial or sites can naturally heal	No effect	No effect	***Public: Naturally heal*** ***Managers: Projects crucial***
2) Projects science-based / science doesn't fit	No effect	No effect	No effect
3) Prioritize visibility / more severe post-fire effects	Severity[1]	No effect	No effect
4) Prioritize livestock / higher densities of invasive annual grasses	No effect	No effect	No effect
5) Native species only / non-natives are acceptable	No effect	No effect	No effect
6) Treat more acres / increase monitoring length	No effect	No effect	No effect
7) Prioritize political pressure / more severe post-fire effects	Severity[1]	No effect	***Managers: political>severity***
8) Prefer to treat more acres / use the best tools	No effect	No effect	No effect
9) Droughts and/or floods are a danger to local ecosystems	Drought/flood concern[1]	No effect	Managers: not concerned/ne[2] Public: Naturally heal, Managers: concerned/neutral
10) Long-term shifts in local temperatures are a danger to local ecosystems	No effect	***Managers: definitive*** ***Public: science doesn't fit*** ***Managers: Neutral***	No effect

[1] When managers felt public want precise policy followed (*n* = 18), no managers prioritized visibility, only 1 prioritized political pressure, and no manager felt droughts/floods are not a concern

[2] Not significant; however, trend mirrors project effectiveness (manager opinion contrary to public opinion)

likely to prefer non-natives and think temperatures are not a concern. When managers felt public want science-based projects, they tended to be less neutral about temperatures.

Trade-Off Decisions

Manager and public respondents were both more likely to prioritize severely degraded sites over livestock (Table 2.8). Managers prioritizing livestock were more likely to have lived in the region for < 5 years, work primarily in the field, work for the BLM, recreate frequently in rangelands, and think projects are crucial to site rehabilitation (Appendix B, Q. 29). Public respondents prioritizing livestock were less likely to trust agencies, agree with policy, or be concerned about invasive grasses and forbs; they were more likely to live close to past wildfires but less likely to consider themselves at high risk of future wildfires (Appendix C, Q. 21). Managers overwhelmingly selected severity over visibility and political pressures (Tables 2.9 and 2.10); it was not statistically reasonable to analyze factors associated with differing responses for these tradeoffs. Possible associations with variables were mentioned when ~ 100% chose one option.

Table 2.8
Manager and public surveys: Prioritize livestock or annual grass invasion

Managers	Public	
78%	66%	A site with high invasion of cheatgrass or red brome (and more likelihood of wildfire)
22%	33%	A site with lower invasion of cheatgrass or red brome, but more use by domestic livestock

*1% DK/NA

Table 2.9
Manager and public surveys: Prioritize visibility or ecosystem effect

Managers	Public	
6%	7%	Locations where the public will see treatments on a regular basis.
94%	91%*	Locations where the post-wildfire ecosystem effect is the most severe.

*2% DK or NA

Table 2.10
Manager survey trade-off: Political pressure versus post-wildfire ecosystem severity

4%	Sites deemed important by political pressure
96%	Sites where the post-wildfire ecosystem effect is the most severe

Time Frames and Funding

In both interviews and surveys (Table 2.1 and Table 2.11), managers were not convinced funding policies that only allowed for 1-3 years of monitoring were long enough to ensure successful rehabilitation. Veteran managers and those with greater personal wildfire risk were more likely to prefer smaller ≥ 5-year projects, while newer managers tended to feel shorter funding cycles were sufficient; however, managers over 60 were also more likely to think short-term spending is sufficient (Appendix B, Q. 31).

In both semi-structured interviews and structured surveys, managers were relatively split whether the time to submit post-wildfire proposals (7 days for emergency stabilization and 21 days for rehabilitation) is sufficient. Those that felt time frames are insufficient were more likely to spend time in the field (either for work or recreation), more likely to think policy is unrealistic, more likely to think larger public, interest likely to think locals agree with management decisions. In other words, those that felt time frames are too short tended to perceive less social-political pressure and also tended to be in the field more (slightly removed from social-political pressure exposure).

Table 2.11
Manager survey: Time frames and funding sufficiency

Do the time frames for submitting rehabilitation plans post-wildfire containment provide adequate time to assess a site and develop an effective strategy? *N* = 233, 91%

Never	Usually not	Neutral	Usually	Always	N/A
4%	31%	18%	36%	4%	7%

How often do you change the initial proposal based on ecosystem characteristics that may have been missed in the time-frame allowed? *N* = 232, 91%

Never	Rarely	About half the time	Almost every time	Every time	N/A
1%	37%	26%	10%	2%	24%

How often do you have to cut back the initial proposal based on funding allocated? *N* = 231, 90%.

Never	Rarely	About half the time	Almost every time	Every time	N/A
0.4%	10%	27%	29%	12%	21%

I prioritize: *N* = 219, 86%

39%	Short-term spending (1-3 years) as an effective means to restore lands
61%	Long-term spending (5-8 years) to ensure effective rehabilitation, even if it means less acreage can be covered

A large majority of managers felt lack of funding causes regular changes to their initial proposals (~ 90% in each agency: BLM, FS, and NPS, Appendix B, Q. 24). Increased local and interest group involvement and increased climate concerns were associated with more regular funding-caused proposal changes. Overall these results suggest that if social-political aspects of the system increase (e.g., if outside parties are interested in their projects) time frame length and funding are more likely considered an issue.

Most managers, especially those working for BLM or FS in the Great Basin, felt interest groups are concerned about post-wildfire projects (68% vs. 12% agree, Table 2.5). Interest group concern was most likely for those with local and larger public also concerned (and locals do not agree with decisions) and increased perceptions of wildfire risks (Appendix B, Q. 34). Managers were most likely to think interest groups prioritize science-based projects, but were split regarding interest group project effectiveness opinion and policy preferences (Tables 2.13–2.15).

Beliefs about interest group concerns and opinions were associated with some management preferences (Table 2.12); often these managers' opinions conflicted with their perceptions of interest group opinions (i.e., they believe interest groups think sites can naturally heal, whereas managers were more likely to think projects are crucial and incorporate non-native species). Interest group concern was also associated with increased uncertainty about project effectiveness overall and increased concern about precipitation risks.

Policy Effectiveness

Most managers felt following agency policy precisely does not address specific ecological conditions (Table 2.13). While they were mostly unsure what interest groups and the public think about policy, they were more likely to think interest groups want agencies to follow policy precisely. Managers selecting precise policy themselves were more likely to be urban and male, have mid-range tenure (6-10 years), and frequently recreate in state/national parks (Appendix B, Q. 26). Policy precision was associated with thinking sites can naturally heal, and perceiving public think projects are crucial. Managers were also most likely to think time frames and funding are sufficient and policy and science are realistic. Managers that felt members of the public favor precise policy were more likely to have lived in the community longer; they felt locals are concerned, disagree with management decisions, and want science-based projects (Appendix B, Q. 26). In other words, public support for policy precision may be

Table 2.12
Manager survey: Perceived interest group opinions and manager decisions (IGs = interest groups). ***Bold*** = significant.

	Perceived interest group project concern and opinions			
Management preferences	IGs are concerned about projects	IGs want projects to follow policy precisely	IGs prefer science-based	IGs think projects are crucial
1) Projects are crucial to site rehabilitation / sites can naturally heal		No effect		***IGs: Naturally heal*** ***Managers: Crucial***
2) Projects should be science-based / science often doesn't fit ecosystems	No effect	No effect	***Managers: science doesn't fit***	No effect
3) Prioritize visibility / more severe post-wildfire ecosystem effects	*Visibility*[1]	No effect	***Visibility***	No effect
4) Prioritize livestock / higher densities of invasive annual grasses	No effect	***Severity***	No effect	No effect
5) Prefer native species only / non-natives are acceptable	No effect	***IGs policy: DK*** ***Managers: natives*** ***IGs policy: opinion*** ***Mangers: non-natives***	***Non-natives***	***Non-natives***
6) Prefer to treat more acres / increase monitoring length	No effect	No effect	No effect	No effect
7) Prioritize sites with more political pressure / more severe post-wildfire ecosystem effects	*Political*[2]	No effect	No effect	No effect
8) Prefer to treat more acres / use the best tools	No effect	No effect	No effect	No effect
9) Droughts and/or floods are a danger to local ecosystems	***Concerned***	No effect	No effect	No effect
10) Long-term shifts in local temperatures are a danger to local ecosystems	No effect	No effect	No effect	No effect

[1] not statistically testable; however, when interest groups are not concerned, no managers prioritized visibility

[2] not statistically testable; however, when interest groups are not concerned, no managers prioritized political pressure

Table 2.13
Summary of both manager and public surveys: Policy relevance

Post-wildfire projects should strive to follow agency policy precisely
Post-wildfire agency policy does not always fit specific situations in my area
Don't Know

	DK	Precise policy always	Policy doesn't always fit
I think	17 (8%)	41 (18%)	169 (74%)
Interest groups think	93 (42%)	71 (32%)	60 (27%)
Public think	132 (60%)	18 (8%)	72 (32%)
Public actually think	1%	10%	89%

Table 2.14
Manager and public surveys: Project effectiveness

Post-wildfire projects are crucial to site rehabilitation
The ecosystem will naturally heal itself
Don't Know

	DK	Naturally heal	Projects crucial
I think	9% (21)	14% (32)	76% (170)
Interest groups think	21% (53)	35% (90)	31% (80)
Public think	35% (78)	35% (77)	30% (66)
Public actually think	1%	31%	67%

perceived by some managers as a barrier to project implementation. However, actual survey results for the general public suggest opposition to precise policy: respondents overwhelmingly felt agency policy both doesn't fit local ecology (Table 2.13) and isn't always realistic (58 v 7%, not reported in a table). Those that did favor policy precision often perceived less wildfire and wildfire associated risks (Appendix C, Q. 18). While the majority of public respondents trust agencies (57% v 19%), precise policy was associated with less trust in agencies.

Table 2.15
Manager and public surveys: Should post-wildfire projects be science-based?

Project choices should be based on proven scientific research
Science often doesn’t reflect reality on the ground
Don't Know

	Don’t Know	Science-based	Science unrealistic
I think	17 (8%)	72 (32%)	137 (61%)
Interest groups think	62 (28%)	117 (53%)	43 (19%)
Public think	108 (49%)	41 (19%)	70 (32%)
Actual public	1%	41%	58%

Environmental Considerations

The majority of public respondents agreed with specific management decisions: they felt projects are crucial to site rehabilitation (Table 2.14), reseeding and mulching are effective treatments (77% vs. 4%, 55% vs. 3%, Appendix C: Q. 22, 37, and 38), drill seeding is more effective than aerial seeding (35% vs. 3%). While public still felt agencies effectively stabilize erosion, they were most likely to disagree with this aspect than any of the other effectiveness questions (37% vs. 17%).

Managers were most likely to think projects are crucial to site rehabilitation and slightly more likely to believe interest groups and local communities prefer ecosystems to naturally heal (Table 2.14); however, nearly 25% of managers felt the ecosystem can naturally heal on its own or were unsure about project effectiveness. Those that felt sites can heal without intervention were more uncertain about local, larger public, and interest group project concern (Tables 2.7a and 2.12, Appendix B: Q. 25). They were more likely to think that, unlike themselves, public and interest groups think projects are crucial.

Managers who believe sites can naturally heal were also less likely to be concerned about weather variables (precipitation and temperatures).

Managers thinking public would like sites to naturally heal was associated with the belief public think policy is unrealistic and doesn't fit the local environment. FS managers were highly unlikely to think public want sites to naturally heal (only 1), while they themselves were some of the most likely to prefer sites to naturally heal (Appendix B: Q. 25). While managers were split on public opinion, the majority of public respondents felt projects are crucial (Table 2.14).

Relevance of Science

The majority of managers felt science often does not reflect ecosystem reality (Table 2.15). Managers often felt the public agreed with them and interest groups do not. Those preferring science-based projects were more likely to work for the NPS, think locals do not agree with their decisions, and believe interest groups think science is unrealistic; science-based managers tended to favor precise policy and were more likely concerned about invasive grasses and forbs (Appendix B: Q. 27). Managers felt the public see science and policy adherence as one and the same (science-based projects, policy-based projects), and interest groups and public preferences to be generally aligned.

Public respondents agreed with manager perception; they tended to feel science was often not relevant to individual projects (Table 2.15). However, public respondents were slightly more supportive of science-based projects than managers and less uncertain. Similar to policy-based projects, wildfire risk and associated concerns with personal safety were identified as important predictors of public survey science preference

(Appendix C: Q. 19). More educated members of the public were more likely to trust science. Those that felt reseeding sites and covering seed to protect it are not effective methods were also unlikely to support science in general.

Climate Risks

The majority of managers felt drought and flood events represent a serious concern on their local ecosystems (Table 2.16). Women, and managers living in drier states/regions (e.g., Mojave Desert) were more likely to be concerned about precipitation threats. As weather is such a critical component of semi-arid restoration projects, rather than simply listing variables of the most importance, we wanted to further classify identified variables into the multi-scalar model (Brunson 2014) presented. Predominantly social and political variables were important classifiers of drought/flood risk (Appendix B: Q. 35): 7 coarse scale social political (e.g., time frames, interest group opinions), 9 fine-scale social political (e.g., female, public opinions), 1 wildfire past (years since nearby wildfire), 2 place exposure (e.g., recreation frequency), 4 coarse-scale ecological (e.g., projects are critical), and 0 fine-scale ecological (4 research, chapter 4).

Table 2.16
Manager and public survey climate response summaries. *‘Work’ instead of ‘live’ in manager surveys.

Ecosystems near where I live* are in danger due to drought and/or flood potential.				
	Agree	Disagree	Neutral	NA,DK
Managers	79%	8%	12%	2%
Public	74%	9%	7%	10%
Ecosystems near where I live* are in danger due to long-term shifts in local temperatures.				
Managers	56%	18%	25%	2%
Public	43%	25%	19%	14%

Highlighting the social-political effects on even drought/floods dangers is the relationship between them and perceived interest group concern in post-wildfire projects. Among all managers, 79% were concerned about precipitation and 8% were not concerned (Table 2.16); managers that felt interest groups are concerned about post-wildfire projects were similar (82%, 6%, Table 2.12). However, when managers felt interest groups are not concerned about projects, 19% of managers were not concerned about drought/flood risks (compared to 6 and 8%, X-squared = 12, df = 6, p-value = 0.05).

Similar to managers, public were concerned about precipitation events (Table 2.16); those who were neutral about temperatures were more likely to be concerned about precipitation. Public risk was associated with a wide-variety of social, political, and ecological fine and coarse-scale variables (Appendix C: Q. 30 and 31; Chapter 3, Table 3.2a): 3 coarse-scale social-political (e.g., trust agencies), 17 fine-scale social-political (e.g., local opinions, own or rent), of which 2 were related to future wildfire risks (e.g., wildfire likely) and 5 to place exposure variables (e.g., OHV more frequently, years lived in region), 8 coarse-scale ecological variables (e.g., temperature changes, reseeding is effective), and 7 fine-scale ecological variables (e.g., erosion concern, severity vs. livestock preference).

Although managers were not overwhelmingly concerned about long-term shifts in local temperatures (Table 2.16), many chose to remain neutral (25%) rather than assert they are not concerned at all. Managers concerned about local shifts in temperature were associated with the following variables (Appendix B: Q. 35): 9 coarse scale social-political (e.g., interest group opinions, policy opinions), 8 fine-scale social-political (e.g.,

< 60 years old, large community, local opinions), which include 0 wildfire risk and 2 place exposure variables (e.g., recreation frequency), 4 coarse-scale ecological variables (e.g., projects are crucial, natives species only, precipitation concern), and 0 fine-scale ecological (7 research based variables, Chapter 4).

Public opinions about temperature change were classified with the following variables: 3 coarse-scale social-political (e.g., trust agencies, policy realistic), 7 fine-scale social-political (e.g., local opinions, specific concerns such as smoke), of which 1 wildfire risk (future wildfire likely) and 4 place exposure (lived in community longest, more frequent hunting and fishing), 5 coarse-scale ecological (e.g., drought/flood concerns, science is realistic), and 4 fine-scale ecological (invasive species concerns – none related to research, Chapter 4). Public respondents with the longest community residency were more likely to think temperatures are changing (from 25% shortest to 52% longest residency).

Choosing the Most Effective Tool

The majority of managers preferred using the most effective tool, even if fewer acres could be treated (Table 2.17). Tool preference was associated with 12 variables (Appendix B: Q. 33): 2 coarse scale social-political (proposal time frames and funding selection was much more likely to be associated with social-political values than ecological ones. Managers choosing native species may be more likely to feel supported by interest group agendas and policy (which recommends native species) and believe local disagree with their decisions.

Table 2.17
Manager survey: Trade-off effective tool vs. more acres

71%	Using the most effective tool, even if it means we can't treat as many acres
29%	Using tools that allow us to cover the most acres, even if the tools aren't ideal

Conversely, public respondents were more likely to prefer native seed (Table 2.18). Native seed preference was more likely to be associated with wildfire risks and ecological variables than social-political variables: 2 coarse scale social-political, 3 fine-scale social-political, 3 wildfire risk, 0 place exposure, 6 coarse-scale ecological, and 9 fine-scale ecological variables. Members of the public prioritizing livestock were evenly split regarding seed preference: 51% non-native vs. 49% native seed.

Public Agreement with Management Decisions

While managers tended to believe public and interest groups hold opposite preferences to themselves (also see section: Social engagement), in the public surveys, respondents were actually more likely to agree with manager preferences (Tables 2.13:2.15). For example, in Table 2.14, the majority of managers felt projects are crucial and were split if the public felt the same (many also uncertain regarding local community preferences). However, in public surveys, respondents were twice as likely to think projects are crucial than post-wildfire sites should naturally heal; it should be noted that percentage believing sites should be allowed to naturally heal (30%) was similar to manager’s perceptions. Analysis indicated the public that believed post-wildfire projects are crucial to site rehabilitation were more likely to live in the Great Basin and to perceive the greatest personal wildfire risk (Appendix C: Q. 17). They were nearly identical to managers in their concern about precipitation risks and only slightly less

Table 2.18

Manager and public surveys: Native vs. non-native seed preference

Managers	Public*	
53%	62%	Reseeding with natives, even if it costs more
47%	38%	Reseeding with the species most likely to become established, even if non-native

1% public DK/NA

likely to be concerned about temperatures (Tables 2.16 and 2.17). Public were more likely than managers to prefer reseeding with native-only mixes (Table 2.18). Similar to managers, they overwhelming supported seeding where it is most needed vs. where it is most visible (Table 2.9). They were slightly more likely to prioritize livestock than managers (Table 2.8).

Discussion

Translational ecology seeks to bridge communication gaps between researchers, stakeholders, and managers. Highlighting areas of commonality and dissent may help managers and agencies better communicate restoration goals and evaluate restoration success (both ecologically and socially). Restoration planning efforts that attempt to span social and political boundaries are increasing, yet remain difficult in post-wildfire time frames. Ecological modeling techniques are instrumental to these efforts and yet struggle to identify and incorporate meaningful social-political factors. Our research found coarse- and fine-scale social, political, and ecological factors were associated with public values, public land manager values, and land management attitudes and preferences (Fig. 2.2).

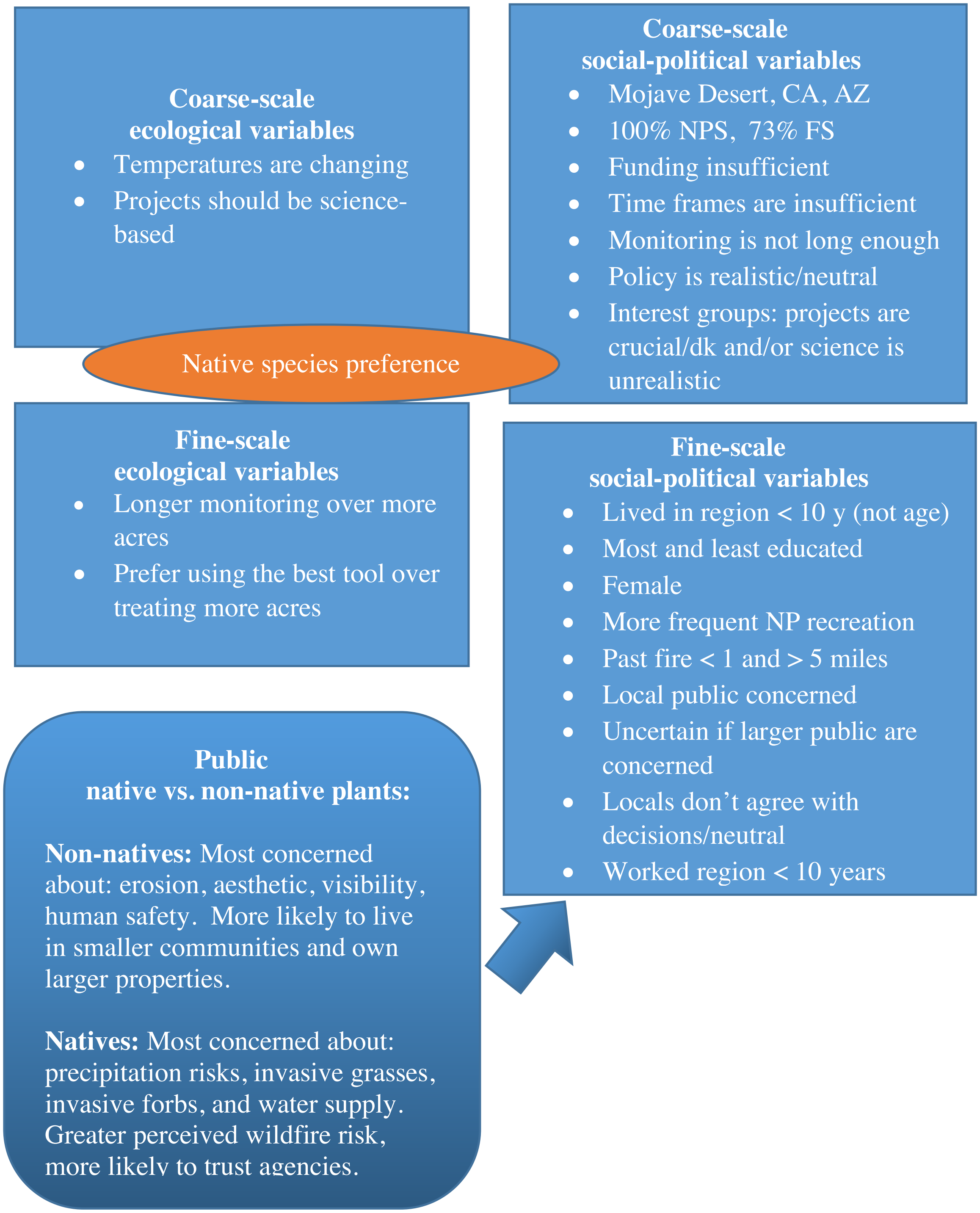

Coarse-scale
ecological variables
Temperatures are changing
Projects should be science-based
Coarse-scale
social-political variables
Mojave Desert, CA, AZ
100% NPS, 73% FS
Funding insufficient
Time frames are insufficient
Monitoring is not long enough
Policy is realistic/neutral
Interest groups: projects are crucial/dk and/or science is unrealistic
Native species preference
Fine-scale
ecological variables
Longer monitoring over more acres
Prefer using the best tool over treating more acres
Fine-scale
social-political variables
Lived in region < 10 y (not age)
Most and least educated
Female
More frequent NP recreation
Past fire < 1 and > 5 miles
Local public concerned
Uncertain if larger public are concerned
Locals don't agree with decisions/neutral
Worked region < 10 years
Public
native vs. non-native plants:
Non-natives: Most concerned about: erosion, aesthetic, visibility, human safety. More likely to live in smaller communities and own larger properties.
Natives: Most concerned about: precipitation risks, invasive grasses, invasive forbs, and water supply. Greater perceived wildfire risk, more likely to trust agencies.

Fig. 2.2. Native species multi-scalar model. Coarse- and fine-scale social, political, and ecological variables associated with manager preference for native species use in post-wildfire restoration projects. Interest group = interest groups.

Manager Values

Public land agencies manage the majority of United States desert habitat. These agencies are highly institutionalized; their rules and norms govern much of decision-maker behavior (Thomas 2003; Wright 2004). Perceptions of barriers (e.g., perceived behavioral control and self-efficacy in the Theory of Planned Behavior) can be just as limiting as actual barriers (Adger et al. 2007). Even when policy directives are in place allowing flexibility, activities that are not perceived as normative or required by policy often will not be pursued (Jantarasami et al. 2010). Land management decisions (livestock priority, seed preference, using the best tools, monitoring length) and values (project importance, science-relevance, policy-relevance, drought/flood cycle changes, and temperature changes) were all significantly associated with several coarse- and fine-scale social, political, and ecological variables. While this was true and expected for the most prominently divisive opinions (e.g., seed preference) it was also true for variables managers overwhelmingly agreed upon (e.g., project importance). Indeed, even with such low numbers for those selecting the least popular choices (e.g., site visibility over most affected sites) our results indicated these managers may be experiencing higher levels of social-political pressures (none choosing site visibility felt locals/interest groups were not concerned about projects). Choosing site visibility may have great social, and therefore some ecological, benefits by garnering public support, involvement, and even willingness to pay taxes (Cabin 2007; Palmer et al. 2007). However, more visible sites may be subject to more disturbances and stress and be less important for habitat connectivity (Meinke et al. 2009). Results from semi-structured interviews indicated some managers may feel proximity and aesthetics drive public acceptance, yet only 6% of managers in the structured survey chose public visibility over ecological need. This may be a result of phrasing, managers choosing what they would ideally prefer rather than what they feel they would likely choose in reality.

As we have found in previous research (Whitcomb 2011), managers remain divided about specific environmental opinions that may have important ecological consequences (e.g., native vs. non-native species, temperature changes). Agency policy recommends the use of native species whenever possible, yet it is difficult to establish native species in semi-arid Great Basin ecosystems (Pyke et al. 2013). Short-term goals associated with non-native species use (e.g., stabilization) have been questioned in recent studies (Rau et al. 2014; Arkle et al. 2014). While differing agency norms placed on native use certainly accounted for some of the split in opinion on this topic, it should not be overlooked that social and interest group norms were also associated with seed preference (Figure 2.2).

Studies evaluating land management success and site prioritization across social-political boundaries often fail to consider social-political coarse- and fine-scale variables (e.g., Meinke et al. 2009 and Arkle 2014). Meinke et al. (2009) omitted areas closer to urban, agriculture, and industrial interests in order to limit increased habitat fragmentation—a fair strategy regarding sage-grouse lek connectivity. However, it also may result in projects actively avoiding people – a strategy that may be unsustainable in these regions experiencing rapid developments and population growth (BLM 2000). We need to understand how social-political factors affect restoration decisions and subsequent success. Results from our study indicate these social-political variables are associated with various land management decisions, from how many acres to treat, to native vs. non-native seed preference.

Land managers make decisions based on technical (e.g., lack of synthesis, lack of time), affective (e.g., lack of trust, cultural barriers), and political barriers (e.g., policy, interest group involvement) (Kearns and Wright 2002). In our study, while manager values were associated with wildfire risks, climate risks, and place exposure variables, these variables were typically more impactful for public respondents. Still, it is important for managers and agencies to recognize the effect of local risks and norm exposure on management decisions. Shared risks, values, and norms may help managers meet citizen concerns and find commonalities more effectively. For example, we found that managers in higher wildfire risk areas may prefer longer-term projects rather than treating more acres. Openly discussing these variables and their impacts on decisions is important to recognize and build trust, and identify leverage concepts of commonality. Discussing shared goals for future generations, can have enormously positive landscape effects and result in cooperative projects that reduce costs to individuals and agencies (Lister et al. 2012).

Climate Risks

Risk perceptions can greatly influence social-political pressure on managers and management decisions (Shackley and Deanwood 2002; McCaffrey et al. 2013). Both managers and public were more likely to be concerned about drought and flood events compared to temperature changes. Precipitation events are much more visually direct compared to temperature effects; it is not surprising respondents were more likely to acknowledge precipitation risks. Communicating project goals around precipitation risks rather than temperature changes may provide more opportunities for public engagement.

That 25% of managers remained neutral regarding local temperature changes, and nearly 20% felt temperatures are not changing, may be some of the most suggestive evidence of local versus institutional influence (where temperature changes are readily acknowledged) on manager values. Ecologically, while manager precipitation and temperature opinions were associated with overall management approaches (e.g., project effectiveness, science relevance), temperature opinion was only associated with one specific management decision (seed preference) and precipitation opinion was not associated with any management decisions. In contrast, public respondents were much more likely to associate climate opinion with their ecological preferences and concerns (e.g., invasive grass concern, reseeding effectiveness). These tendencies not associate precipitation and temperature events/shifts with specific management decisions reflects previous research (Whitcomb 2011) which suggested even managers concerned about local changes in temperature and precipitation were unsure what specific actions they could undertake in restoration projects. A potential barrier regarding manager opinion of temperature change, despite overwhelming research supporting it, may then be this perceived lack of control, the lack of ability or self-efficacy to do something about it.

Ecosystem Risks: Citizen Survey

Members of the public were also asked to rate their concern about post-wildfire ecosystem risks. Outside of wildfire, public respondents were worried in general about invasive grasses and forbs. In a wildfire specific context, however, they indicated more concern about habitat, forage, erosion, and human safety/health. Similar to the findings of O'Neill and Nicholson-Cole (2009), highlighting post-wildfire project benefits to habitat and forage may have more of an impact on attitudes than keying in on suppression of negative aspects (such as invasive species), even in wildfire specific contexts. 'Habitat' and 'forage' may be "leverage point concepts of commonality" for managers hoping to create productive dialogue around trade-off decisions.

Place "Exposure"

Community tenure and recreation frequency increase exposure to local attitudes and are thus likely to affect social norms and values. Both frequency of recreation and length of time living in specific regions and communities were associated with some management opinions and decisions. Managers that recreated more frequently in parks and rangelands were more likely to believe temperatures are shifting and drought/flood events are likely. Place exposure variables were also related to overall project effectiveness, science opinion, and seed preference. While "capture" by local interests has often been viewed as something to avoid (Culhane 2013) the importance of local ecological knowledge for social and ecological resilience is increasing (Fernandez-Gimenez et al. 2008). Increased exposure was often associated with less neutrality about local opinions, suggesting these managers may be more in-tune with local ecological preferences. Managers with more exposure were more likely to select longer monitoring projects and prioritizing use of better tools. Managers' firsthand experience of long-term trends is also likely advantageous; for example more locally tenured managers were more likely to agree temperatures are changing. As Culhane (2013) points out, manager relationships with local groups, rather than “capturing” them, actually may allow them to better leverage conflicting interests against each other while maintaining collaborations (e.g., we really need to clean up this area before litigation stops everything).

For members of the public, increased place exposure increased perceptions that other locals are concerned about projects as well as local agreement and trust with management decisions. Public respondents with greater place exposure were also more likely to be concerned about temperature changes and specific wildfire associated risks. Ultimately, these results may suggest living in a community for longer and recreating more frequently in these regions may support land management goals. Collaboration settings provide a pathway that can increase communication of local ecological knowledge and/or values between managers and stakeholders.

Bridging Communication Gaps Post-wildfire

Wildfires can devastate properties, impact health and safety, and influence numerous ecosystem services (Daniel et al. 2007). Not surprisingly, as wildfire risks increase, local and interest group concern in post-wildfire projects also increases—it is simply more relevant. Wildfire and climate risks were more predictive of public opinions than manager decisions. While it is encouraging that the local community responding to this survey was generally supportive of management decisions, managers that perceived interest group pressures were also more likely to perceive local pressures. This suggests simultaneous social and political pressure on managers when one or the other occurs, which may explain some manager’s perceptions that local residents hold opposing opinions to their own. Our survey assessed the interested, but not necessarily involved, public. Managers are more likely to interact with public actively involved or affected by management decisions; in other words, they may come into more contact with those who hold differing views rather than those who support their decisions. It is important for managers, agencies, and communities to recognize which land management decisions may be more supported than they perceive, especially when developing policy. Additionally, understanding which aspects of post-wildfire restorations members of the public are most concerned about can both help agencies and managers communicate project goals and may provide opportunities to engage locals in citizen science efforts.

Public perception of project importance was most likely to be driven by ecological and personal risk concerns (e.g., wildfire risk, precipitation risks). Locals at higher risk of post-wildfire consequences (larger properties, closer to fire, rural) tended to support agencies, but also seemed concerned that projects may not be as effective as they could be, especially regarding erosion, habitat, and forage. Positive messaging (e.g., *benefits* of the project for *increased* forage) rather than negative messaging (e.g., *decreasing invasive* grasses) may be more effective while still conveying the same project goals (Vaske and Kobrin 2001, O'Neill and Nicholson-Cole 2009). "Invasive," in addition to being jargon (Nay and Brunson 2013), is also subject to scientific debate (e.g., are species truly invasive? Introduced? Exotic? Encroaching?); conversely the terms 'forage' and 'habitat' may be less controversial and thus more easily convey goals. This research also suggests areas with higher wildfire risks may result in more local support for native species. In situations where managers would prefer to use natives, this information could lessen manager reticence to suggest native use. In situations where managers might prefer to use non-natives, highlighting the benefits to 'habitat and forage' as well as reducing wildfire risk may be helpful, and/or redirecting local engagement into the support of successional restoration projects.

In this study, local and interest group involvement was associated with managers being less likely to practice the "art" of management and more likely to follow policy precisely. This was often contrary to actual public opinions and preferences. Involving local communities in restoration efforts may address both manager constraints and public concerns. Active public involvement increases procedural justice (Lawrence et al. 1997) and directly addresses clarity of land management decisions through hands-on learning (McKinley et al. 2015).

Policy and Political Considerations

Recently, federal funding length was changed to provide for up to 5 years post-wildfire monitoring when necessary (DOI 2016). Whether 5 years is long enough ecologically, and how often longer monitoring is approved, remains to be seen. Additionally, in these funding constrained environments, longer funding for monitoring may decrease funding for other aspects of projects, such as number of acres that can be treated. We wanted to understand if managers agreed with the overall concept of reallocating resources to ensure projects are successful ecologically, while treating less land. Our analysis suggests reallocation of funds was generally supported by managers and associated with very few variables aside from experience and wildfire risk.

Short time-frames to submit post-wildfire proposals may decrease the necessary flexibility of land management. Some studies are questioning the forces driving these time frames (e.g., precipitation uncertainty, need for stabilization). New research suggests a pattern of decreasing precipitation following big fire years (Pilliod 2015) – can and/or should post-wildfire projects wait to reseed until the region enters a more reliable "wet period"? More reliable climate down-scaling would clearly be needed to justify that argument, and would still be subject to the vagaries of weather. In the meantime, investing in mulching, water-retentive seed coating, and/or irrigation techniques seems highly recommended. Emergency stabilization of soils is a common justification for short proposal time frames and categorical exemptions. However, recent studies have suggested stabilization efforts involving range drilling may not provide these benefits even in the short-term (Miller et al. 2012; Pyke et al. 2013; Wagenbrenner et al. 2013). New research also indicates biological soil crusts (intricate communities of moss, lichen, and cyanobacteria that bind soils together) may not be as absent post-fire, even severe ones, as previously thought (Aanderud 2014 and Chapter 4), and may recover some binding cyanobacteria relatively quickly (Aanderud 2014). This could potentially decrease the need for emergency stabilization on sites with patchy or less severe fires; however, more research is needed. Longer time frames would also provide increased opportunities for public involvement in the project development stage, which may support longer term site resilience past the scale of agency funding through citizen science efforts. Finally, longer time frames could allow universities to get involved on projects, which could pull funding from multiple sources and alleviate some of the public lands financial burden.

Managers preferring policy to be followed precisely tended to perceive more public and interest group involvement and took a "business as usual" management approach. They also tended to be more decisive in their ecological opinions when interest groups were involved. These indicate some potential barriers to collaborative projects from the management perspective. The overall impression that interest groups' involvement may be considered a barrier to project implementation and flexibility, is supported in previous studies (Karkkainen 2002, MacGregor and Seesholtz 2008). While managers tend to view the NEPA policy and process as complementary and supportive to ecological and climate adaptation (Jantarasami et al. 2010), the tendency to hinder constructive social-political dialogue highlights some serious implications for project success. The intractability that interest group and public involvement continues to convey to managers can, and should, be reframed into opportunities for learning (Daniels and Walker 1996). Project participants (managers and public) may be viewed initially as clinging rigidly to one solution, while collaborative processes inherently create flexibility and dialogue. The conventional NEPA process may also convey the message that public interest is an accommodation (Daniels and Walker 1996); additionally, rather than finding commonalities, the process highlights narrow interests.

While very few managers preferred to choose the most visible sites over those most severely affect by fire, those that did almost universally perceived political pressures. One concern with prioritization modeling is that the models typically select locations closer to human populations as being of lower priority because they are subject to increased disturbance and fragmentation (Meinke et al. 2009). However, visibility of successful projects can increase community support by mechanisms such as enhancing place attachment or influencing perceived norms (Manning 2009) – additionally, these wildfire-urban-interface areas typically face some of the greatest costs and urgency for agencies to control wildfire. Prioritization models need to account for these social variables in a better capacity.

Overall this study suggests that if any aspect of the system is slightly different, and/or if outside parties are interested in projects, current policies are perceived as too restrictive. Choosing to base projects on science was perceived as contrary to public and interest groups' preferences; when interest groups are involved, managers felt they used policy and science as barriers to stop projects. One of the goals of NEPA was to encourage procedural justice in locally affected communities (Lawrence et al. 1997; Karkkainen 2002). The reality of this process is that excessive appeals and litigation often require agencies to devote considerable time and resources to making proposal science and policy irrefutable (Karkkainen 2002; United States Forest Service 2002). Rigidly following policy to minimize NEPA appeals is antithetical to collaboration theory and on-the-ground management goals. For collaboration to be constructive, especially in the face of conflict, science needs to be discussed in a fair and just political process, but must also encourage learning, dialogue, and flexibility (Lee et al. 1995). Daniels and Walker (1996) found in a high conflict area (~ 4200 letters received in response to a draft Environmental Impact Statement 90 day comment period), supplementing the NEPA process with workshops was highly effective in finding commonalities, directing agency measures, and supporting agency actions.

Implications

This research identifies coarse- and fine-scale social and political factors associated with land management decisions. Post-wildfire projects face unique challenges in addressing social and political considerations; they are often categorically exempt from the public comment process and yet these same projects may have some of the most influence on public perceptions regarding agency effectiveness. Restructuring project goal messaging may assist agencies and managers hoping to engage more effectively with local communities. Workshops, local meetings, and citizen science projects can decrease unidirectional flows of information and increase public procedural justice. Modeling efforts that account for social components of both proposed and past restoration projects will likely be more robust than those lacking these components. As we strive to mitigate wildfire and improve ecosystem services, it is becoming apparent that social components must be accounted for to achieve regional success. When we recognize bridging political boundaries (e.g., private and state lands) is critical to large-scale ecosystem resilience, the value of increasing dialogue and trust becomes clear.

Key Points

1. Managers perceived social values to be more oppositional than they actually were.
2. Perceived social and political pressures were associated with manager ecological decisions and opinions and were often perceived as a barrier to preferred project implementation and use of “best science.”
3. Current methods for social dialogue (public comment periods) are not sufficient on their own, methods that actively engage local communities are more likely to be successful.
4. Ecological modeling that hopes to address region-wide restoration efforts must better address social-political factors.

References

Aanderud, Z, 2014. Biological soil crusts and fire in Utah's West Desert [Fact sheet]. In Desert Fire, Mammal, and Plant Studies. Available at: http://desert-fmp.org/wp-content/uploads/2014/06/Aanderud-fact-sheet.pdf (Accessed 15 March 2017).

Adger, WN, 2000. Social and ecological resilience: are they related? Progress in Human Geography, 24, 347–364.

Adger, WN, Agrawala, S, Mirza, MMQ, Conde, C, O'Brien, K, Pulhin, J, Pulwarty, R, Smit, B, Takahashi, K, 2007. Assessment of adaptation practices, options, constraints and capacity. Climate change, 200.

Ajzen, I, 1991. The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179-211.

Allen, SD, Wickwar, DA, Clark, FP, Dow, RR, Potts, R, Snyder, SA, 2009. Values, beliefs, and attitudes technical guide for Forest Service land and resource management, planning, and decision-making. Gen. Tech. Rep. PNW-GTR-788. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 112 pp.

Arkle, RS, Pilliod, DS, Hanser, SE, Brooks, ML, Chambers, JC, Grace, JB, Knutson, KC, Pyke, DA, Welty, JL, Wirth, TA, 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere, 5(3), 1-32.

Barry, SJ, 2014. Using Social Media to Discover Public Values, Interests, and Perceptions about Cattle Grazing on Park Lands. Environmental management, 53(2), 454-464.

Blanchard, B, Ryan, RL, 2007. Managing the wildland–urban interface in the northeast: perceptions of fire risk and hazard reduction strategies. Northern Journal of Applied Forestry, 24(3), 203-208.

Breiman, L, Cutler, A, 2007. Random Forest http://www.stat.berkeley.edu/~breiman/RandomForests/cc_home.htm (Accessed 15 March 2017).

Bright, AD, Newman, P, Carroll, J, 2007. Context, Beliefs, and Attitudes toward Wildland Fire Management: An examination of residents of the wildland-urban interface. Human Ecology Review, 14(2), 206-216.

Brunson, MW, 2012. The elusive promise of social-ecological approaches to rangeland management. Rangeland Ecology and Management, 65(6), 632-637.

Brunson, MW, 2014. Unwanted no more: land use, ecosystem services, and opportunities for resilience in human-influenced shrublands. Rangelands, 36(2):5-11.

Brunson, MW, Baker, MA, 2015. Translational training for tomorrow's environmental scientists. Journal of Environmental Studies and Sciences, 1-5.

Brunson, MW, Shindler, BA, 2004. Geographic variation in social acceptability of wildland fuels management in the Western United States. Society and Natural Resources, 17, 661–678.

Brussard, PF, Charlet, DA, Dobkin, DS, Ball, LC, Bishop, KA, Britten, HB, Fleishman, E, Fleury, SC, Jenni, T, Kennedy, TB, Mullen, CO, 1998. Great Basin-Mojave Desert region. Status and trends of the nation's biological resources. US Geological Survey, 2.

Bureau of Land Management (BLM), 2000. The Great Basin: healing the land. National Interagency Fire Center, Boise, ID. 36 pp.

Cabin, RJ, 2007. Science-Driven Restoration: A Square Grid on a Round Earth?. Restoration Ecology, 15(1), 1-7.

Carroll, J, Bright, A, 2009. The integrative complexity of wildfire management scale: Are we there yet. Human Ecology Review, 16(2), 211-221.

Clewell, AF, Aronson, J, 2006. Motivations for the restoration of ecosystems. Conservation Biology, 20(2), 420-428.

Cohn, PJ, Williams, DR, Carroll, MS, 2008. Wildland–urban interface residents' views on risk and attribution. In: Martin, WE, Raisch, C, Kent, B, 'Wildfire risk: human perceptions and management implications', Resources for the Future: Washington, DC, pp. 23–43.

Coppock, DL, Fernández-Giménez, M, Hiernaux, P, Huber-Sannwald, E, Schloeder, C, Valdivia, C, Arrendondo, J, Jacobs, M, Turin, C, and Turner, M, 2015. Rangelands in developing nations: conceptual advances and societal implications. In: Briske, D (Ed.), Rangeland Systems: Processes, Management, and Challenges. Springer.

Cortner, HJ, Wallace, MG, Burke, S, Moote, MA, 1998. Institutions matter: the need to address the institutional challenges of ecosystem management. Landscape and Urban Planning, 40(1), 159-166.

Cramer, LA, Kennedy, JJ, Krannich, RS, Quigley, TM, 1993. Changing Forest Service values and their implications for land management decisions affecting resource-dependent communities. Rural Sociology, 58(3), 475-491.

Creswell, JW, 2009. Editorial: Mapping the field of mixed methods research. Journal of Mixed Methods Research, 3(2), pp.95-108.

Culhane, PJ, 2013. Public lands politics: Interest group influence on the Forest Service and the Bureau of Land Management. Routledge.

Cutler, DR, Edwards, TC, Beard, KH, Cutler, A, Hess, KT, Gibson, JC, Lawler, JJ, 2007. Random forests for classification in ecology. Ecology 88(11), 2783-2792.

Daniel, TC, Carroll, MS, Moseley, C, 2007. People, fire, and forests: a synthesis of wildfire social science. Corvallis: OSU Press.

Daniels, SE, Walker, GB, 1996. Collaborative learning: improving public deliberation in ecosystem-based management. Environmental impact assessment review, 16(2), 71-102.

Dellasala, DA, Williams, JE, Williams, CD, Franklin, JF, 2004. Beyond smoke and mirrors: a synthesis of fire policy and science. Conservation Biology, 18(4), 976-986.

Dillman, DA, 2007. Mail and Internet surveys: the tailored design, second edition-2007 update. New York: John Wiley, 565 pp.

Fernandez-Gimenez, ME, Ballard, HL, Sturtevant, VE, 2008. Adaptive management and social learning in collaborative and community-based monitoring: a study of five community-based forestry organizations in the western USA. Ecology and Society, 13(2), 4.

Flint, CG, 2007. Changing forest disturbance regimes and risk perceptions in Homer, Alaska. Risk Analysis 27, 1597–1608.

Fox, RJ, Crask, MR, Kim, J, 1988. Mail survey response rate a meta-analysis of selected techniques for inducing response. Public Opinion Quarterly, 52(4), 467-491.

Germain, R, Floyd, D, Stehman, S, 2001. Public perceptions of the USDA Forest Service public participation process. Forest Policy and Economics, 3, 113–124.

Glaser, B, Strauss, A, 1967. The discovery of grounded theory: Strategies for qualitative research. New York: Aldine Publishing Company.

Grese, RD, Kaplan, R, Ryan, RL, Buxton, R, 2000. Psychological benefits of volunteering in stewardship programs. In: Gobster, PH, Hull, B, (Eds.), Restoring nature: perspectives from the social sciences and humanities. Island Press, Washington, D.C. pp.265–280.

Hallett, LM, Diver, S, Eitzel, MV, Olson. JJ, Ramage, BS, Sardinas, H., Statman-Well, Z, Suding, KN, 2013. Do we practice what we preach? Goal setting for ecological restoration. Restoration Ecology, 21:312-319.

Heberlein, TA, Baumgartner, R, 1978. Factors affecting response rates to mailed questionnaires: A quantitative analysis of the published literature. American Sociological Review, 447-462.

Huberman, AM, Miles, MB, 1983. Drawing valid meaning from qualitative data: some techniques of data reduction and display. Quality and Quantity, 17, 281-339.

Jackson, EL, 1986. Outdoor recreation participation and attitudes to the environment. Leisure studies, 5(1), 1-23.

Jantarasami, LC, Lawler, JJ, Thomas, CW, 2010. Institutional barriers to climate change adaptation in US national parks and forests. Ecology and Society, 15(4), 33.

Karkkainen, BC, 2002. Toward a smarter NEPA: monitoring and managing government's environmental performance. Columbia Law Review, 102, 903-972.

Kearns, S, Wright, V, 2002. Barriers to the use of science: USDA Forest Service case study on fire, weed, and recreation management in wilderness. Unpublished Report. 70 p. On file at: Leopold Institute, P.O. Box 8089, Missoula, MT 59807.

Kennedy, JJ, 1985. Viewing wildlife managers as a unique professional culture. Wildlife Society Bulletin, 13(4), 571-579.

Kennedy, JJ, Thomas, JW, Glueck, P, 2001. Evolving forestry and rural development beliefs at midpoint and close of the 20th century. Forest Policy and Economics, 3(1), 81-95.

Knapp, CN, Fernandez-Gimenez, ME, 2009. Knowledge in practice: Documenting rancher local knowledge in northwest Colorado. Rangeland Ecology and Management 62, 500-509.

Kneeshaw, K, Vaske, JJ, Bright, AD, Absher, JD, 2004a. Acceptability norms toward fire management in three national forests. Environment & Behavior, 36, 592-612.

Kneeshaw, K, Vaske, JJ, Bright, AD, Absher, JD, 2004b. Situational influences of acceptable wildfire management actions. Society and Natural Resources, 17, 477-489.

Knutson, KC, Pyke, DA, Wirth, TA, Pilliod, DS, Brooks, ML, Chambers, JC, 2009. A Chronosequence Feasibility Assessment of Emergency Fire Rehabilitation Records Within the Intermountain Western United States—Final Report to the Joint Fire Science Program—Project 08-S-08. US Geological Survey Open-File Report, 1099.

Knutson, KC, Pyke, DA, Wirth, TA, Arkle, RS, Pilliod, DS, Brooks, ML, Chambers, JC, Grace, JB, 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. Journal of Applied Ecology, 51(5), 1414-1424.

Larson, LR, Whiting, JW, Green, GT, 2011. Exploring the influence of outdoor recreation participation on pro-environmental behaviour in a demographically diverse population. Local Environment, 16(1), 67-86.

Lawrence, RL, Daniels, SE, Stankey, GH, 1997. Procedural justice and public involvement in natural resource decision making. Society and Natural Resources, 10(6), 577-589.

Lee, B, Haworth, L, Brunk, C, 1995. Values and science in impact assessment. Environments, 23(1), 93–100.

Lister, R, Smith, P, Torrez, S, Baker, S, 2012. Innovative Partnership Formed to Restore the West Potrillos. Rangelands, 34(4), 31-34.

Machlis, GE, 2002. Burning questions: A social science research plan for federal wildland fire management (No. 943). Idaho Forest, Wildlife and Range Experiment Station, College of Natural Resources, University of Idaho.

MacGregor, DG, Seesholtz, DN, 2008. Factors influencing line officers' decisions about National Environmental Policy Act project design and development. General Technical Report PNWGTR-766. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

Manning, C, 2009. The psychology of sustainable behavior: Tips for empowering people to take environmentally positive action. Minnesota Pollution Control Agency.

McCaffrey, SM, 2004. Fighting fire with education: what is the best way to reach out to homeowners? Journal of Forestry, 102(5), 12-19.

McCaffrey, SM, Olsen, CC, 2012. Research perspectives on the public and fire management: a synthesis of current social science on eight essential questions. Gen Tech Rep NRS-104. USDA Forest Service, Northern Research Station, Newtown Square, PA, 40 pp.

McCaffrey, SM, Toman, E, Stidham, M, Shindler, B, 2013. Social science research related to wildfire management: an overview of recent findings and future research needs. International Journal of Wildland Fire, 22(1), 15-24.

McKinley, DC, Miller-Rushing, AJ, Ballard, HL, Bonney, R, Brown, H, Evans, DM, French, RA, Parrish, JK, Phillips, TB, Ryan, SF, Shanley, LA, 2015. Investing in citizen science can improve natural resource management and environmental protection. Issues in Ecology, 19.

Meinke, CW, Knick, ST, Pyke, DA, 2009. A spatial model to prioritize sagebrush landscapes in the Intermountain West (USA) for restoration. Restoration Ecology 17(5):652-659.

Miller, ME, Bowker, MA, Reynolds, RL, Goldstein, HL, 2012. Post-fire land treatments and wind erosion–lessons from the Milford Flat Fire, UT, USA. Aeolian Research, 7, 29-44.

Kursa, MB, Rudnicki, WR, 2010. Feature Selection with the Boruta Package. Journal of Statistical Software, 36(11), 1-13. Available at: http://www.jstatsoft.org/v36/i11/ (Accessed 18 August 2013).

Moote, MA, McClaran, MP, Chickering, D, 1997. Theory in practice: applying participatory democracy theory to public land planning. Environ Manag 21(6):877–889

Nardi, E, 2009. Fewer cattle to graze Walnut Creek. TriValley Herald, Pleasanton, 3–4

Nardi, E, 2012. Walnut Creek residents say goats not enough to help control fire danger. San Jose Mercury News, 28 June 2012. Available at: http://www.mercurynews.com/breaking-news/ci_20965480/walnutcreek-residents-say-bring-back-cows-goats. (Accessed 18 August 2013).

Nay, CG, Brunson, MW, 2013. A war of words: do conflict metaphors affect beliefs about managing "unwanted" plants?. Societies, 3(2), pp.158-169.

O'Neill, S, Nicholson-Cole, S, 2009. "Fear won't do it" Promoting positive engagement with climate change through visual and iconic representations. Science Communication, 30(3), 355-379.

Palmer, M, Allan, JD, Meyer, J, Bernhardt, ES, 2007. River restoration in the twenty-first century: data and experiential knowledge to inform future efforts. Restoration Ecology, 15(3), 472-481.

Peterson, R, Coppock, DL, 2001. Economics and demographics constrain investment in Utah private grazing lands. Journal of Range Management, 54(2), 106-114.

Pellant, M, Shaver, P, Pyke, DA, Herrick, JE, 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO., 122 pp.

Pilliod, DS, 2015. Fire, rain, and post-fire restoration of sagebrush steppe in the Great Basin. Restoring the West Conference, Oct 28-29 2015, Utah State University, Logan, UT.

Pyke, DA, Wirth, TA, Beyers, JL, 2013. Does Seeding After Wildfires in Rangelands Reduce Erosion or Invasive Species? Restoration Ecology, 21(4), 415-421.

Rau, BM, Chambers, JC, Pyke, DA, Roundy, BA, Schupp, EW, Doescher, P, Caldwell, TG, 2014. Soil resources influence vegetation and response to fire and fire-surrogate treatments in sagebrush-steppe ecosystems. Rangeland Ecology and Management, 67(5), 506-521.

R Development Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing,Vienna, Austria. Available at: http://www.R-project.org. (Accessed 29 Mar 2016).

Renn, O, Webler, T, Wiedemann, P, 1995. Fairness and competence in citizen participation: evaluating models for environmental discourse. Kluwer Academic, Boston.

Rieber, A, 2011. Residents of California neighborhood demand return of cows. Western Livestock J, 90(38), 1–7.

Rowe, G, Frewer, LJ, 2000. Public participation methods. An evaluative review of the literature. Science, Technology and Human Values 25(3), 29.

Ryan, R, Hamin, E, 2008. Wildfires, communities, and agencies: stakeholders' perceptions of post-fire forest restoration and rehabilitation. Journal of Forestry, 106, 370–379.

Sayre, N, 2010. Climax and "Original Capacity": the science and aesthetics of ecological restoration in the southwestern USA. Ecological Restoration, 28, 23-31.

Schlesinger, WH, 2010. Translational ecology. Science, 329(5992), 609.

Shackley, S, Deanwood, R, 2002. Stakeholder perceptions of climate change impacts at the regional scale: implications for the effectiveness of regional and local responses. Journal of Environmental Planning and Management, 45, 381-402.

Shindler, B, Brunson, MW, Stankey, GH, 2002. Social acceptability of forest conditions and management practices: a problem analysis. Environment and Society Department (ENVS) Faculty Publications, Utah State University, Logan, UT.

SurveyMonkey, Inc. Whitcomb, H. Post-wildfire Policy and Practice, http://www.surveymonkey.com/s/ (last visited Oct. 8 2013) Company: SurveyMonkey Inc. Location: Palo Alto, California, USA

Tarrant, MA, Cordell, HK, Green, GT, 2003. PVF: a scale to measure public values of forests. Journal of forestry, 101(6), 24-30.

Thomas, CW, 2003. Bureaucratic landscapes: interagency cooperation and the preservation of biodiversity. Massachusetts Institute of Technology Press, Cambridge, Massachusetts, USA.

Toledo, D, Kreuter, UP, Sorice, MG, Taylor Jr., CA, 2012. To burn or not to burn: ecological restoration, liability concerns, and the role of prescribed burning associations. Rangelands 34(2):18-23.

Toledo, D, Sorice, MG, Kreuter, UP, 2013. Social and ecological factors influencing attitudes toward the application of high-intensity prescribed burns to restore fire adapted grassland ecosystems. Ecology and Society 18(4): 9.

Toledo D, Kreuter UP, Sorice, MG, Taylor Jr., CA, 2014. The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems. Journal of Environmental Management ,132, 323-328

US Department of the Interior and US Department of Agriculture, 2016. Interagency Standards for Fire and Fire Aviation Operations NFES #2724. Ch 11 Incident Management. Available at: http://www.fws.gov/fire/handbook/2016%20Chapter%2011%20Incident%20Management.pdf (Accessed 15 May 2017).

United States Forest Service (USFS), 2002. The process predicament: how statutory, regulatory, and administrative factors affect national forest management. U.S. Forest Service, Washington, D.C., USA.

Vaske, JJ, Kobrin, KC, 2001. Place attachment and environmentally responsible behavior. The Journal of Environmental Education, 32(4), 16-21.

Vaske, JJ, Bright, AD, Absher, JD, 2008. Salient value similarity, social trust, and attitudes toward wildland fire management strategies. Fire Social Science Research From the Pacific Southwest Research Station: Studies Supported by National Fire Plan Funds, 233.

Vining, J, Ebreo, A, 1991. Are you thinking what I think you are? A study of actual and estimated goal priorities and decision preferences of resource managers, environmentalists, and the public. Society and Natural Resources 4,(2), 177-196.

Vogt, CA, Winter, G, Fried, JS, 2005. Predicting homeowners' approval of fuel management at the wildland–urban interface using the theory of reasoned action, Society and Natural Resources, 18, 337–354.

Wagenbrenner, NS, Germino, MJ, Lamb, BK, Robichaud, PR, Foltz, RB, 2013. Wind erosion from a sagebrush steppe burned by wildfire: measurements of PM 10 and total horizontal sediment flux. Aeolian Research, 10, 25-36.

Walker, B, Holling, CS, Carpenter, SR, Kinzig, A, 2004. Resilience, adaptability and transformability in social-ecological systems. Ecology and Society, 9(2), 5.

Walker, B, Salt, D, 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Washington, DC, USA: Island Press. 174 pp.

Weick, KE, Sutcliffe, KM, 2011. Managing the unexpected: Resilient performance in an age of uncertainty (Vol. 8). John Wiley & Sons.

Whitcomb, HL, 2011. Temperature increase effects on sagebrush ecosystem forbs: experimental evidence and range manager perspectives. All Graduate Theses and Dissertations. Paper 1044. Available at: http://digitalcommons.usu.edu/etd/1044 (Accessed 16 March 2017).

Winter, G, Fried, JS, 2000. Homeowner perspectives on fire hazard, responsibility, and management strategies at the wildland-urban interface. Society & Natural Resources, 13(1), 33-49.

Wirth, TA, Pyke, DA, 2007. Monitoring Post-fire Vegetation Rehabilitation Projects: A Common Approach for Non-forested Ecosystems. DIANE Publishing.

Wright, V, 2004. How do land managers adopt scientific knowledge and technology? Contribution of the Diffusion of Innovations theory. In: Munro, N, Dearden, P, Herman, TB, Beazley, K, Bondrup-Nielson, S, (Eds.), Making Ecosystem-based management work. Proceedings of the Fifth International Conference on Science and Management of Protected Areas, Victoria, BC, 11-16 May 2003

Yin, RK, 1994. Case study research: design and methods. 2nd ed. Thousand Oaks, CA, USA: Sage Publications. 219 pp.

CHAPTER 3

POST-WILDFIRE INNOVATION ADOPTION IN THE GREAT BASIN AND MOJAVE DESERT: BRIDGING COMMUNICATION GAPS BETWEEN RESEARCHERS AND MANAGERS

Abstract

Wildfires are increasing in frequency, severity, and intensity in the Great Basin and Mojave Desert. Researchers are working hard to provide new tools and methods that can assist land managers in their efforts. And yet, short post-wildfire proposal time frames and increasingly limited funding may limit manager ability to effectively incorporate new science. Social, political, and ecological influences on post-wildfire manager attitudes regarding both general support of experimental research and specific research results may provide important information to agencies and researchers wanting to encourage new post-wildfire science. Post-wildfire manager attitudes seem to be partially influenced by social and political factors (Chapter 2); however post-wildfire proposals often receive categorical exemption status under the National Environmental Policy Act (NEPA), and the public comment process is bypassed. Thus, it is relatively unknown if the public supports new research on post-wildfire restoration projects or if managers feel supported by social-political variables to incorporate new research. An online survey was emailed to > 1,600 managers whose job titles appeared to be related to post-wildfire restoration; 256 responses were received. Public surveys were mailed to 1,000 residents in rural and urban Great Basin and Mojave Desert zip codes. Both attitudes toward research and coarse- and fine-scale social, political, and ecological variables that may influence support for research were identified, using Brunson's (2012, 2014) multi-scalar model of social-ecological systems and a cost-time value lens. While the majority of managers and citizens supported experimental research in general, managers were less able to consider incorporating more specific research results into actual projects, especially when cost and time constraints were added. Managers were also more uncertain regarding local community and interest group support.

Keywords: Innovation adoption, post-wildfire restoration, social-ecological systems

Introduction

Interagency wildland fire policy (USDA and USDI 2003) mandates the use of "best available science" as well as quickly implementing new science on post-wildfire projects. Yet the sheer volume of research make synthesis into actual rehabilitation plans difficult (Wright 2010). Indeed, reports from the United States Government Accountability Office indicated major lags in implementation of new restoration research on public lands (USGAO 2003, 2006). In the Great Basin between 1990 and 2013, public land agencies have conducted at least 1,600 post-fire rehabilitation treatments on 2.2 million ha, or 6%, of the region (Pilliod and Welty 2013). Recent estimates indicate wildfires burn up to 1 million ha of Great Basin lands each year, increasing the number of post-wildfire treatments. In 2007 alone, $60 million was spent on federal public lands Emergency Stabilization and Rehabilitation (ESR) projects. Given this enormous dedication of resources to post-wildfire rehabilitation in the Great Basin, finding pathways that can improve incorporation of new research is important.

Not much is known about manager interest in specific post-wildfire related research. As part of the Desert Fire, Mammals, and Plants research project, we evaluated manager interest in collaborating researchers' scientific results. We surveyed managers regarding post-wildfire restoration considerations to more generally understand factors that influence whether managers are able to adopt new tools or techniques. Because theory suggests normative and political factors can influence decisions, we also surveyed members of local communities in these regions where land managers live, to see whether the attitudes and beliefs of managers reflect those of their local social system.

'Innovation adoption' is defined as the experimentation, diffusion, and eventual incorporation of new practices into a current management (Rogers 1995). Attributes of innovations that can affect rate of diffusion include: relative advantage (better than previous methods), compatibility (new method is consistent with values, experiences, and needs), complexity (degree of difficulty to understand and use new methods), trialability (possibility for time-limited experimentation), and observability (degree results are visible). In addition to Rogers' theory of innovation, several social science theories are relevant to post-wildfire innovation adoption: Theory of Planned Behavior, Applied Behavior, Norm Theory, and Capture Theory.

In 1991 Icek Ajzen refined his previous Theory of Reasoned Action into the Theory of Planned Behavior (TPB). This theory suggests that attitudes about a behavior influence the likelihood that the particular behavior will occur; attitudes about a behavior are developed through subjective norms and perceptions of behavioral control. Subjective norms are a person's perception that important other people want them to behave a certain way (e.g., superiors, colleagues, neighbors, friends). Behavioral control refers to the belief that changing a behavior is within the realm of a person's control (e.g., ability/infrastructure to incorporate seed coating technology) and self-efficacy, or the perception of the difficulty of the task (already scarifying seed vs. no pre-treatment). Additionally, people are more likely to behave a certain way if they hold positive attitudes toward the behavior, believe important others hold positive attitudes toward the behavior, and believe the behavior will lead to a desired outcome. Applied Behavior theory, in the most general sense, states behavior is a direct result of consequences (Skinner 1953). In the land manager decision framework this could be defined as incentives and disincentives such as institutional rewards (promotions, raises) or perceived institutional barriers such as NEPA appeals and litigation. Indeed, Wright (2010) found that the majority of fire *mitigation* managers not only viewed NEPA appeals as barriers to implementation, but even the anticipation of litigation prevented managers from considering innovations. Norm Theory addresses cultural incentives; people behave or act in a way they believe other people (e.g., colleagues, neighbors, friends) want them to behave (Hovland et al. 1953; Ajzen and Fishbein 2005). Capture Theory (Barney and Nader 1974; Culhane 2013) is a derivative of Norm Theory and suggests that a shift in subjective norms can occur from prolonged or important/influential association with a particular culture or community; "captured managers" allegedly act in the interests of a single community or stakeholder group to the detriment of other groups.

Land managers make decisions influenced by technical, emotional, and political barriers (Kearns and Wright 2002). A major barrier to management adoption is the diffusion of knowledge or awareness of new research (Wright 2004). Managers are already constrained in time and resources; finding new research, calculating associated costs, and implementation time is not often realistic. Additionally, the public land agencies managing the majority of Great Basin wildfire-prone areas are highly institutionalized - their rules and norms govern a large portion of decision-maker behavior (Thomas 2003; Jantarasami et al. 2010). Managers also make ecological and social-political trade-off decisions. When evaluating benefits and costs of a new practice, the often-increased cost of a new technique likely decreases the amount of acreage that can be treated. Institutional rewards may be differentially persuasive for acres treated over innovation (Wright 2010). For example, agencies typically communicate their progress to the public in terms of how many millions of acres were seeded post-wildfire, not whether those reseedings were actually successful 1, 3, or 5 years later. Recent research evaluating long-term restoration success confirms seeding success is predominantly precipitation-based, drilling having little effect on restoration goals in lower elevations (and drier than average year) or when non-native species are used (Arkle et al. 2014; Knutson et al. 2014). Additionally, our semi-structured interviews with managers indicated incorporating a new practice into formal proposals may take longer, placing the entire project at risk of not receiving any money in new competitive funding landscapes (one example of a compatibility barrier to innovation, Rogers 1995). Limited funding may also cause the proposed action to be denied or removed later, placing less benefit on attempted inclusion costs and effort.

While innovation in the face of these institutional barriers may seem hopeless, agencies have adopted top-down and bottom-up innovations (e.g., multiple-use mandates and increased use of minimum-till drills, respectively). Choosing to implement new research requires that the user (agency or manager) is interested, can understand it, and has a positive attitude toward it (Rogers 2003). This process inherently takes time, the amount of which is dependent on communication networks, social norms, and individual characteristics. Pannell et al. (2006) suggest that adoption in rural landscapes primarily requires the new practice to demonstrate ‘relative advantage’ compared to previous methods and ‘trialability’ or proof of significant effect. Both concepts were reflected in a recent study by Bruce et al. (2014) who found perceived behavioral control (skills or resources that make a behavior easier or more difficult to perform) was the strongest predictor of manager intention to use volunteers. The general principle driving restoration ecology is to assist successional processes or state changes (SER 2004) that will either accelerate or change the trajectory of a landscape’s biotic community toward resilience. Similarly, a main premise of Innovation Theory is that assisting communication of effective strategies may increase restoration success and resilience both spatially (landscape connectivity) and over time (norms, public investment in the practices).

While Innovation Adoption Theory provides a rigorous foundation for science uptake in organizations, diffusion typically focuses on unidirectional approaches. Unidirectional approaches to innovation sometimes involve useless steps, as the general premise is that of convincing the end-user of the utility of the product or technique without ascertaining end-user actual interest until much later in the process. For example, in the Rocky Mountain Research Station Science Application and Integration Program (USFS 2004), the cycle of science distribution does not include the end-user until the Delivery and Trial stage (Problem Formulation → Research →Interpretation → Development → Delivery and Trial → Adoption → Problem Formulation). Additionally, unidirectional diffusion efforts (e.g., unidirectional education) may result in frustration, weak public support, and implementation barriers (Renn et al. 1995; Moote et al. 1997; Rowe and Frewer 2000; Germain et al. 2001).

A Translational Ecology framework expands upon Innovation Adoption by incorporating communication that focuses on iterative and adaptive learning processes (Brunson and Baker 2015). Translational science is a relatively new tool for ecologists. It originated in the medical field to bridge the gap between technical jargon-rich medical science and the patient's ability to use and understand the science (Schlesinger 2010). At a time when numerous manager and researcher institutional barriers slow down the dissemination of ecological research to on-the-ground managers (Cortner et al. 1998; Wright 2007, 2010; O'Donnell et al. 2010), translational science has emerged as a possible solution (Schlesinger 2010). The same RMRS cycle can be applied, but by incorporating collaboration in the early stages, translational approaches suggest complicated efforts and slow diffusion rates to convince specific managers of research utility can be discarded. Translational ecology surmises that effective applied research and innovation can only occur with transparency and communication of attitudes, beliefs, and intentions from managers, researchers, and stakeholders (Schlesinger 2010). Otherwise information flow stagnates, attitudes and beliefs are misinterpreted, and intentions may unnecessarily vary. Research may end up at cross-purposes with what managers or stakeholders want. Post-wildfire rehabilitation practices that do not seem to consider ecological context may seem incongruent with best-practices to stakeholders and researchers. Translational ecology provides an approach that can bridge these concerns in conjunction with essentially unidirectional NEPA processes.

Translational Ecology and other social-ecological systems collaborations are beginning to gain recognition with regard to ecological resilience, ecosystem connectivity, and long-term public stewardship. However, institutional capacity for post-wildfire translational projects is and will likely remain elusive in the foreseeable future on post-wildfire projects region-wide. Thus, a social-ecological systems multi-scalar model (Brunson 2012, 2014) was applied to surveys to fill these translational gaps in understanding and communication between post-wildfire public land managers, researchers, and stakeholders (Fig. 3.1 from Brunson 2014).

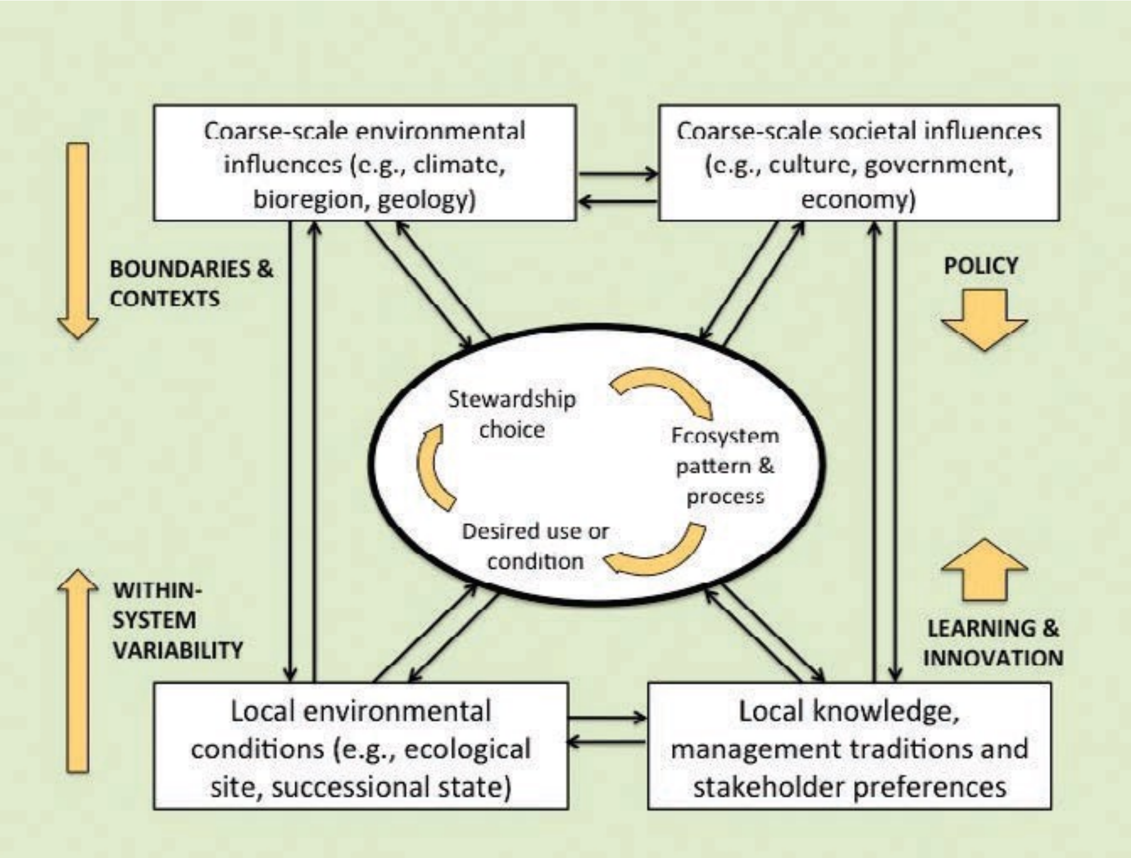

Coarse-scale environmental influences (e.g., climate, bioregion, geology)
Coarse-scale societal influences (e.g., culture, government, economy)
BOUNDARIES & CONTEXTS
POLICY
Stewardship choice
Ecosystem pattern & process
Desired use or condition
WITHIN-SYSTEM VARIABILITY
LEARNING & INNOVATION
Local environmental conditions (e.g., ecological site, successional state)
Local knowledge, management traditions and stakeholder preferences

Fig. 3.1. Multi-scalar model. This research attempts to fill communication gaps of post-wildfire projects using a multi-scalar model of social-ecological systems (Brunson 2014). In this model coarse- and fine-scale social-political and ecological variables create iterative feedbacks on decision making and ecosystem patterns.

In the multi-scalar model, Brunson (2014) defines “leverage points” as the adjustable influential elements that can make a treatment strategy more effective. Coarse-scale leverage points likely require policy changes, while local or fine-scale leverage points can be addressed through learning and/or innovation. Surveys of managers and stakeholders provide valuable insights about social, political, and ecological coarse-scale leverage points that policy-makers can consider, and fine-scale leverage points managers and researchers can address through learning and innovation.

As part of the Desert Fire, Mammal, and Plant Studies research project (desert-fmp.org), we explored leverage points pertaining to specific research of collaborating scientists. Desert FMP was a research project funded by the United States Department of Agriculture, National Institute of Food and Agriculture to investigate underlying causes and consequences of fire and invasive grasses in the Mojave Desert and Great Basin. Improving understanding of these factors, can enhance prediction and management of wildfire risk. Participating researchers explored red brome invasion, restoration seed predation, halogeton control, role of fertile islands, pollination strategies, and biological soil crusts (recovery, hydrology, and soil stability).

These each represent potential determinants of project success and/or methods that can ultimately save money, yet are unlikely to be currently utilized by most post-wildfire managers. As mentioned, theory suggests managers will be more likely to adopt practices that exhibit relative advantage, compatibility, and are relatively simple to understand and use (Rogers, 1995). Additionally, practices are more likely to be adopted if they are associated with positive attitudes (including positive feelings toward perceive behavioral control) and positive consequences (incentives). However, risks associated with new techniques can also influence adoption (Toledo et al. 2012). Past experience of wildfire and likelihood of future wildfire can create either social barriers or opportunities for innovations. While personal climate risks have been shown to influence land manager decisions (Shackley and Deanwood 2002), it is currently unknown how or if personal wildfire risks and/or local climate risks influence post-wildfire manager decisions.

In addition to personal characteristics such as age, gender, and education, we hypothesized climate and personal wildfire experiences and risks (wildfire risks to personal property) would influence Great Basin and Mojave Desert land manager attitudes. Because theory suggests normative and political factors can also influence decisions, we hypothesized local community attitudes, and increased exposure to attitudes (e.g., years lived in a community) would reflect manager attitudes regarding post-wildfire decisions. Cumulatively, we hypothesized that decisions about whether to adopt post-fire rehabilitation innovations are influenced by both coarse- and fine-scale factors in both the social and ecological components of a system. In sum, we surveyed managers about post-wildfire restoration considerations to understand the adoptability of the findings from Desert FMP (as well as characterizing factors that influenced manager ability to adopt new techniques in general). Translational Ecology suggests iterative feedbacks can improve social-ecological communication. We used a translational framework to test these hypotheses and provide feedback to managers and researchers. As costs and time considerations represent such likely barriers to post-wildfire managers in particular, and to provide better translational feedback to researchers regarding public land manager innovation adoption potential, I propose a four-level framework that describes an innovation's degree of novelty and condition of barriers (Figure 3.2). This

“Best Management Practices” Low CTV *Most likely*	Best Management Practices High CTV
New methods Low CTV	New methods High CTV *Least likely*

Fig. 3.2. Public lands manager innovation framework: Cost-Time-Value (CTV) lens. Refers to cost, time, and/or perceived value of proposed innovation.

framework is based on “Best Management Practices,” “New Practices,” and a “Cost-Time-Value (CTV) lens.” The CTV lens addresses innovation diffusion variables in a more concise two-dimensional measure: *Cost* and *time* encompass compatibility and trialability, while *value* includes relative advantage, complexity, and observability. Further description of the CTV lens can be found in the Methods section of this chapter. Land managers’ CTV barriers were examined in semi-structured interviews and used to predict general land manager support of innovations and research presented. The term “best management practices” originated in the Federal Clean Water Act (1977 33 U.S.C. § 1251 et seq.): “a practice or combination of practices that is determined by a state to be the most effective means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.” While official definitions vary by state, the intent remains the same. On rangelands, best management practices often follow Natural Resources Conservation Service Technical Guide recommendations (USDA 2012). Here we use best management practices to refer to common practices used on the majority of post-wildfire projects in western United States semi-arid rangelands.

Methods

Structured Survey – Post-wildfire Managers

A structured survey instrument (Appendix B) was designed based on semi-structured interviews (Chapter 2) and collaborating researcher ecological science tofurther elucidate the interplay of fine and coarse social-political and ecological variables and test specific hypotheses. The survey was divided into 4 general sections each addressing coarse- and fine-scale attributes: social characteristics (general, job, wildfire), policy context (time-frame and funding constraints), stakeholder perceptions alignment (opinions, trade-off decisions, and public concerns), and ecological study results (research partners results).

Social Characteristics

Three characteristics were included due to their common predictive power in surveys: age, gender, and education. Region was separated into three categories: Great Basin, Mojave Desert, and southern Great Basin. Brussard et al. (1998) summarize the complexity and differences in flora and fauna of the transition zone between the Great Basin and Mojave Desert. We hypothesized variables in the survey might represent different trade-offs for southern Great Basin managers compared to either of the other regions. Using the transition zone descriptors Brussard et al. (1998) identified (115 kilometers wide and encompassing shifts in dominant floristics, elevation, temperature, and precipitation from rain to snow), field office summaries supplied by agency websites, and Google Earth (Map data ©2016 Google), we identified which field offices could reasonably be categorized as southern Great Basin.

In addition to general and workplace characteristics, managers were asked their perceptions of local climate and personal wildfire risks. Personal risk experience/perception (e.g., past exposure to wildfire or flooding) have been found to influence manager decisions (Shackley and Deanwood 2002). While local norms were tested directly (in the next section) by asking perceptions of local opinions, living in a community longer, and recreating more frequently on public lands during non-work related time, are also likely to increase exposure to local norms. Collectively, we refer to these predictors as place "exposure."

Local community respondents also vary in their risk perceptions (wildfire, climate, and ecosystem) and place "exposure" (residency length, recreation frequency, recreation type); these variations may influence public trust of post-wildfire projects. When these risks are perceived at their highest, does the public support experimental research? Does management support of general experiments and specific research change when more groups (public and interest groups) are perceived to be involved? Identifying the relative influences of perceptions such as these is an important aspect to understanding the social-ecological context of post-wildfire decisions.

Policy Context

Institutions unintentionally and yet inherently create barriers through policy for on-the-ground decision-makers (Cortner et al. 1998). In interviews (Chapter 2), land managers discussed two pervasive institutional barriers in post-wildfire landscapes: time-frames for assessing the landscape post-wildfire and funding limitations (competition and funding length). Managers expressed concern that even if they successfully compete for the limited funds available the funding length (at the time of the survey 1-3 years) were just not ecologically realistic. Recently, land management agencies have responded to this common concern by lengthening monitoring and subsequent treatment response post-project to 5 years, when "needed" (DOI 2016). It remains to be seen if managers, researchers, and stakeholders find this to be sufficient, or how this affects funding for other proposal components.

Stakeholder Opinions

The third section of the survey evaluated post-wildfire ecological trade-off decisions, especially with regard to perceived social and political opinions and pressures. From the interviews (Chapter 2), it was clear that a majority of managers at some point experienced outside political or social pressure regarding their post-wildfire decisions. In the context of innovation adoption, this section tested how manager social/ political/ ecological trade-offs might relate to interest in new research (e.g., if managers think locals agree with their post-wildfire decisions are they more or less likely to have positive attitudes toward research presented?). This section contained many identical questions to the public survey, for comparison of what managers think and what members of local communities actually think (Chapter 2). For this chapter, public respondents' opinions were compared to public respondents' support of experimental research in general.

Ecological Research Responses

The fourth and final section of the manager survey was designed to address specific research results of collaborating researchers from the Desert-FMP project. Researchers on this project studied ecosystem responses to fire in the Mojave Desert and the Eastern Great Basin. Research areas included in this survey were: biological soil crusts, *Bromus rubens* (red brome), pollination strategies, fertile islands, small mammals, and *Halogeton glomeratus*. The survey included a brief synopsis of each researcher's preliminary findings. Managers were asked to assume, for the purpose of this study, that "all results remain consistent with the preliminary results over time. This will help us determine the context of our study implications and help guide our future research."

Questions regarding biological soil crust were prefaced with the following findings: "Central Great Basin: Intense fire resulted in loss of Biological Soil Crust, decreased N-fixation, water infiltration, and soil stability. After just two years, soil stability is starting to return. Mojave Desert: Trends are difficult to see in the short-time frame so far; while soil stability is returning, soils remain much less stable than the Central Great Basin soils two years post-fire."

Questions regarding fertile islands and pollination were prefaced with the following: "Precipitation, fine soils, and fertile islands positively affected seed productions. The more specialized pollination strategy a plant has, the worse fire was for its reproductive viability."

Small mammal questions were prefaced with the following synopsis: "1. Burning shifted Mojave Desert small mammal population to kangaroo rat dominance. K-rats selectively predate native plant species. 2. Small mammals presence suppresses halogeton invasion. 3. In burned plots with small mammals excluded, SEEDLING survival was much higher (61%) than in non-exclusion plots (9%).” This survey provided a unique opportunity to sample a large population of post-wildfire managers about utility of these researchers' scientific endeavors prior to the Delivery and Trial stage (USFS 2004).

Cost-Time-Value Lens

We operationalized the Cost-Time-Value lens as an approach to post-wildfire translational feedback between managers and researchers. To do this, we defined the context specific nature of *cost*, *time*, and *value* to post-wildfire managers. Cost is not simply the financial cost of the procedure, but the cost of personnel, the cost of the manager’s time to research, evaluate, include the procedure, and the risk/cost of not receiving funding. Regarding this last point, proposals that incorporate new unproven research may also result in not receiving funding for that particular innovation (therefore also a waste of time to the manager and agency dollars) and may result in their proposal being delayed and thus not receiving funding at all.

Time barriers include lack of time to read and incorporate new research, short time frames for submitting proposals, and lack of time to implement new research on-the-ground. Wright (2010) found time was the number one barrier to incorporation of best science into fire and fuels management. Time (and costs) also encompass perceived social and political pressures, such as litigation potential. Even the possibility of litigation can tie many managers’ hands (Wright 2010). Evaluation of litigation cost/time barriers suggests researchers should consider how to most effectively address potential conflicts when presenting their results to managers.

To have value an innovation must present clear advantages (relative advantage and trialability as discussed above) to the manager and the ecosystem (Rogers 2003; Pannell et al. 2006). For example, managers are subject to the vagaries of weather – many projects attempt to reseed in the fall so seed is in place in the spring when plant available water is more reliable. Seed coating technologies that effectively enhance water retention seem clearly advantageous (Madsen et al. 2012), yet if the seed coating cost crosses a threshold, the value to the manager who needs to treat ever larger areas of land may be significantly reduced. Value of specific research was assessed directly for four questions (e.g., Presence of fertile islands would affect how we reseed spatially: "absolutely," "if we had the money," "if we had the time," etc.) and indirectly (statistical association between responses to research and funding adequacy question) for all 11 research questions and general experiment support.

In the CTV lens, I present a 2x2 model of Best Management Practices, new science, and CTV. In this model, post-wildfire management contexts are described with the following:

- *BMP – low CTV*: A BMP with low cost, time, or value (ecological, social, political) barriers is the ultimate goal of rangeland restoration science and practice. This box tends to refer to the most frequently used practices, such as drill seeding post-wildfire. Drill seeding is not always low CTV, depending on social-ecological context.
- *BMP – high CTV*: Best management practices with high cost, time, and/or value barriers can be as simple as the cost/time required to using a minimum-till drill on flat slopes, or complex as seed provenance.

- *New methods – low CTV*: An example of a new method with relatively little cost, time, or value constraints could be assessing biological soil crusts when already assessing other ecological characteristics; initial training would likely be the biggest costs.
- *New methods – high CTV*: Finally, an example of a new method with high cost, time, or value barriers could be costs and time associated with assessing small mammal abundance, and increasing seed and/or excluding small mammals if abundance is high.

This lens can be used by researchers when evaluating the utility of their proposed research and presenting past research in journals, to extension, or at conferences (e.g., bulleted at the beginning of a research article).

Coarse- and Fine-scale Variables

Recognizing that division into different scale variables and categories is subjective, we separated responses into coarse- and fine-scale social, political, and ecological variables (Appendix B and C). The manager survey asked 13 coarse-scale social-political questions (5 related to interest group opinions), 25 fine-scale social political question (including 4 wildfire questions and 7 place exposure questions), 6 coarse-scale ecological questions, and 16 fine-scale ecological questions (11 related to interest in new research). The public survey asked 6 coarse-scale social-political questions (1 related to interest groups and 2 related to trust in agencies), 31 fine-scale social-political variables (including 4 wildfire questions and 15 place exposure), 9 coarse-scale ecological variables, and 12 fine-scale ecological variables.

Survey Administration

The manager survey was administered to land managers throughout the Great Basin and Mojave Desert using SurveyMonkey, Inc., an online survey tool. All 1,624 managers identified were emailed a letter of information and the survey in February 2013. Active emails were confirmed by the software and questionnaires were delivered to 1,490 individuals. Two reminder emails were sent and the survey was kept open until May 1^{st}.

Land managers may feel compelled to make certain decisions based on their perception of general population opinions and values (norm activation, risk of political action). A structured paper survey was mailed to 1,000 residents of the Great Basin and Mojave Desert (Appendix A). ZIP codes in the Great Basin and Mojave Desert were identified and given to Survey Sampling International (SSI®). SSI® provided 1,000 randomly derived mailing addresses within the ZIP codes. Following Dillman's design (2007) for maximizing survey response, postcards were sent in May 2013 to the mailing addresses, requesting participation in the study, noting university sponsorship, and providing follow-up contacts. All of these traits have been shown to increase response rates (Heberlein and Baumgarner 1978; Fox et al. 1988). Postcards were followed one week later by a more in-depth information letter, the survey itself, and a postage-paid return envelope. Another postcard was sent ten days later thanking those who had participated and encouraging non-respondents that their participation was essential. This was followed 10 days later by one final round of information letters, surveys, and return envelopes sent only to those participants who had not yet responded (918).

The structured surveys tested five hypotheses. Hypothesis 1: Personal characteristics will influence post-wildfire manager attitudes to research. Hypothesis 2: Personal climate and wildfire risks will influence attitudes to research. Hypothesis 3: Increased exposure to local norms and manager perceptions of local community attitudes will reflect manager attitudes to research. Hypothesis 4: Cost-time variables will influence manager attitudes to research. Hypothesis 5: Coarse- and fine- social, political, and ecological variables will influence public land managers' and local communities' attitudes toward research.

Data Analysis

Manager and public surveys were analyzed using the same methods. Repeated random forest classification trees were run on each response variable using the Boruta package (Miron et al. 2010) in R. This package repeats random forests classification trees up to 498 times, taking anywhere from < 1 minute to 10 minutes to run for any given model in this dataset. Because successive trees do not depend on earlier trees, and sampling is random each time, repeated random forest analysis generates fewer false positives than parametric techniques, and increases accuracy of the binary decision split (i.e., node purity, Breiman and Cutler 2007). In principle, when strong interactions are likely to be present, random forest decision trees should outperform linear regression methods (Cutler et al. 2007). At each node, the number of predictors available are restricted which ensures correlations are small. Classification trees do not compute traditional statistical results (p-values, coefficients, or confidence intervals)—they are used for classification of important variables.

Pearson's Chi-squared test for given probabilities were performed for every combination of response variables in both structured surveys. These were used to further evaluate any statistically significant relationships of interest. Pearson's Chi-squared test for given probabilities were performed to test the independence of the column and row variables. By default, the p-value is computed from the asymptotic chi-squared distribution of the test statistic (with continuity correction when 2-by-2). However, if an error arose (e.g., small expected cell counts), a Monte Carlo simulation test was used with 2000 replicates. Monte Carlo simulation tests never resulted in different interpretation, and so was omitted from results reporting for simplicity.

Results

The majority of managers supported experimental post-wildfire treatments (Table 3.1). Questions relating to biological soil crusts (BSC) had highest response rates compared to other questions (> 80%, Table 3.1) while action pertaining to small mammals had some of the lowest response rates (~ 65%); rather than reflecting manager interest, this may have been due to survey fatigue as BSC questions were asked first and small mammals last (Appendix B: Q. 36-45). Ability to consider research topics, when adjusted for response rate, was highest for small mammals for halogeton response, halogeton/ small mammals herbicide, and BSC rather than vegetation as a measure of soil stability. Managers were most uncertain regarding whether or not to control halogeton and whether kangaroo rats are a concern in their projects (Frequencies in Table 3.2a and Appendix B: Q. 36-45).

Table 3.1

Land manager responses to research presented. Answers categorized as ability/willingness to 'consider,' which included agree with methodology adjustment, agree with methodology adjustment 'if we had the money/time,' and agree research area is a concern (Kangaroo rats and halogeton). In ability/willingness to consider research was categorized as 'discard,' and included those that answered: 'Doesn't matter,' 'Neutral,' or 'DK.' 'Consider' and 'discard' were also adjusted based on response rate to each question.

Survey Question	Response rate (N/256)	Consider ('Absolutely' + 'if we had the money/time')	Consider *response rate	Discard (doesn't matter + neutral/dk)	Discard *response rate
1) I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet	224, 88%	81%	71%	19%	17%
2) Check one: When applying for funding post-wildfire, assessing Biological Soil Crust could help us assess hydrology and soil stability faster / Our present methods are accurate and sufficient without assessing Biological Soil Crust.	208, 81%	58%	47%	42%	34%
3) Vegetation loss is a more reliable indicator of soil stability than Biological Soil Crust.	219, 86%	20%	17%	72% (37% + 35%)	62%
4) Presence of fertile islands would influence how we reseed spatially (Check all that apply: Absolutely + Cost & time barriers)	203, 79%	66% (27% +39%)	52%	44% (14% + 30%)	35%
5) If a wildfire is patchy in nature, I would prioritize seed from species that are pollinated by specialist insects and let the wind-pollinated and less specialized species reseed on their own. (Check all that apply: Absolutely + Cost & time barriers)	201, 79%	54% (15% + 39%)	43%	44% (14% + 30%)	35%

Table 3.1 continued

Survey Question	Response rate (N/256)	Consider (‘Absolutely’ + ‘if we had the money/time’)	Consider *response rate	Discard (doesn’t matter + neutral/dk)	Discard *response rate
1) Do you consider Kangaroo rats a nuisance species post-wildfire?	196, 77%	24%	18%	76% (19% + 57%)	59%
2) Given these results, if Kangaroo rat density is high, would you increase your seeding density?	171, 67%	62% (13% +59%)	42%	27%	18%
3) Would you apply for funding to exclude or control Kangaroo rat density?	164, 64%	52% (9% +43%)	33%	48%	31%
4) I am concerned about halogeton post-wildfire	187, 73%	42%	31%	58% (12% + 46%)	42%
5) I typically request money for halogeton control post-wildfire	187, 73%	7%	5%	93% (32% + 61%)	68%
6) If small mammal abundance is high, I would request less money for halogeton herbicide treatments	186, 73%	15%	11%	85% (15% + 70%)	62%
7) If small mammal density is high, I would request money to (Check all that apply: increase seeding density, change seeding timing, exclude small mammals, other)	167, 65%	76%	49%	24%	16%

Table 3.2a

Manager innovation adoption summary. Significant predictor groups (e.g., interest group pressures) of manager interest in innovation.

Response rate to each question and Answer frequencies	Wildfire risks 4	Coarse-scale Social-political 12 (Interest group)	Fine-scale Social-political 25 (5 Local, 7 exposure)	Coarse-scale Ecology 5 (2 climate)	Fine-scale Ecology 17 (11 research)
I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet.					
N = 224, 88% Agree, 81% Disagree, 6% Neutral, 11%, NA 2%	2	6 (2 Interest group)	4 (2 Local, 2 exposure)	5 (Precipitation Temperature)	7 (7 research)
A. When applying for funding post-wildfire, assessing biological soil crust could help us assess hydrology and soil stability faster. B. Our present methods are accurate and sufficient without assessing biological soil crust.					
N = 208, 81% A = 58% B = 42%	1	4 (2 Interest group)	8 (2 Local, 5 exposure)	5 (Temperature)	4 (4 research)
Vegetation loss is a more reliable indicator of soil stability than biological soil crust.					
N = 219, 86% Agree, 37% Disagree, 20% Neutral, 35%, NA 9%	0	10 (4 Interest group)	12 (3 Local, 4 exposure)	5 (Precipitation Temperature)	9 (8 research)
Presence of fertile islands would influence how we reseed spatially.					
N = 203, 79% Absolutely, 27%, If we had the: Money,14%, Time, 7%, Both, 17% Doesn't matter, 7%, I Don't Know, 28%	3	6 (3 Interest group)	5 (1 Local, 4 exposure)	1	7 (7 research)
If a wildfire is patchy in nature, I would prioritize seed from species that are pollinated by specialist insects and let the wind-pollinated and less specialized species reseed on their own.					
N = 201, 79% Absolutely, 15%, Money, 13%, Time, 12%, Both, 14% DM:14%, DK:30%	0	5	4 (1 Local, 1 exposure)	4 (Temperature)	9 (9 research)

Table 3.2a continued

Response rate to each question and answer frequencies	Wildfire risks 4	Coarse-scale Social-political 12 (Interest group)	Fine-scale Social-political 25 (5 Local, 7 exposure)	Coarse-scale Ecology 5 (2 climate)	Fine-scale Ecology 17 (11 research)
Do you consider Kangaroo rats a nuisance species post-wildfire?					
N = 196, 77% Always, 6%, Sometimes, 18%, Neutral, 26%, No, 29%, DK, 32%	0	7 (3 Interest group)	6 (2 Local, 2 exposure)	2 (Temperature)	12 (10 research)
Given these results, if Kangaroo rat density is high, would you increase your seeding density?					
N = 171, 67% Absolutely 13%, If we had the: Money 46%, Time 4%, Both 9% Doesn't matter 27%	1	5 (1 Interest group)	6 (2 Local, 1 exposure)	5 (Precipitation Temperatures)	6 (6 research)
Would you apply for funding to exclude or control Kangaroo rat density?					
N = 164, 64% Absolutely 9%, If we had the: Money 24%, Time 6%, Both 13% Doesn't matter 48%	0	3 (1 Interest group)	2 (1 Local, 2 exposure)	2 (Precipitation)	7 (7 research)
I am concerned about Halogeton post-wildfire.					
N = 187, 73% Agree 42% Disagree 12% Neutral 21%, DK 25%	1	9 (2 Interest group)	6 (2 Local, 1 exposure)	3	8 (8 research)
I typically request money for Halogeton control post-wildfire.					
N = 187, 73% Agree 7% Disagree, 32% Neutral, 29%, DK 32%	0	7 (1 Interest group)	3 (2 Local)	3	8 (8 research)

Table 3.2a continued

Response rate to each question and answer frequencies	Wildfire risks 4	Coarse-scale Social-political 12 (Interest group)	Fine-scale Social-political 25 (5 Local, 7 exposure)	Coarse-scale Ecology 5 (2 climate)	Fine-scale Ecology 17 (11 research)
If small mammal abundance is high, I would request less money for Halogeton herbicide treatments.					
N = 186, 73% Agree, 15% Disagree 15% Neutral, 32%, DK 38%	1	4 (2 Interest group)	9 (3 Local, 4 exposure)	1	9 (8 research)
If small mammal density is high, I would request money to: (Check all that apply)					
N = 167, 65% Some response: 76% Increase seed density, 47% Change seeding timing, 29% Exclude small mammals, 15% Doesn't matter, 24% (> 100% from ability to select multiple options)	2	1	2 (1 exposure)	0	8 (7 research)

Table 3.2b

Local citizen support of experiments summary. Trust = trust agencies, agencies are effective, exposure = place exposure.

	Wildfire risks 4	Coarse-scale Social-political 6 (2 trust)	Fine-scale Social-political 27 (15 exposure)	Coarse-scale Ecology 8 (2 climate)	Fine-scale Ecology (12)
I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet.					
N = 145, 95% Agree, 59% Disagree, 16% Neutral 17%, Don't Know 8%	0	3 (1 trust)	11 (5 exposure)	8 (Precipitation, Temperatures)	8

Hypothesis 1: Personal characteristics will influence post-wildfire manager attitudes to research.

Of the three general characteristics (age, gender, and education), none were related to post-wildfire manager support of experimental research in projects, nor were any work tenure or place exposure variables (Table 3.2a). Age was not a significant predictor for any specific research presented. Female managers were more likely to prefer BSC over vegetation for assessing soil stability (Appendix B: Q. 36-45), less definitive regarding whether or not kangaroo rats were a concern on their landscapes, and more likely to think increasing seed based on kangaroo rats is important (and also more likely to think barriers to increasing seed may be an issue). Managers that were least and most educated (some college or graduate degree) were often similar in their responses (Appendix B: Q. 36-45). They were more likely to prefer BSC over vegetation (mid-range post-fire tenure, suggesting not experience related). Least and most educated managers were more likely to prefer BSC over vegetation, consider pollinator-based seed selection, decrease herbicide used to control halogeton if small mammal densities are high; these selections were also more likely for managers with mid-range post-wildfire and regional tenures perhaps suggesting least and most educated choices are not contrary to experience-based choices. Those with the least education were the most likely to consider action regarding small mammal seed predation. Age, gender, and education were not associated with fertile island research.

Eight job characteristics were included to assess effects of experience and institutional parameters: agency; supervisory role; whether the position is fire-specific or general range management; how long have managers been working in post-wildfire landscapes, region, and current job; whether they work primarily in the office or field; whether they primarily collect data, compile reports, or make final decisions. Manager support of general experimental research in post-wildfire landscapes was not associated with any job characteristics (Appendix B: Q. 35).

Respondents that had been working in post-wildfire landscapes about 6-10 years (mid-range tenure) were the most likely to be interested in research (BSC soil stability, exclude kangaroo rats, adjust halogeton herbicide based on small mammal abundance). Respondents with the longest job tenures were more likely to consider kangaroo rats and halogeton a concern (and also more likely to support increasing seed density to account for predation by kangaroo rats).

Agency employment was only associated with utility of BSC assessments (NPS) and halogeton concern (BLM). While managers with fire-specific job titles were more likely to think kangaroo rats are a threat to reseeding success, managers with non-fire-specific job titles were typically more willing to consider research results (BSC assessments, increasing seed based on kangaroo rats, excluding kangaroo rats, have an opinion about halogeton). Respondents solely responsible for collection of data (no proposal writing) were more likely to support BSC assessments.

It may be important to note that fine-scale ecological variables were some of the least likely variables to be associated with research responses. However, fine-scale ecological variables were necessarily limited and not exhaustive; it is possible that other, non-tested fine-scale ecological variables would have been associated with specific research presented. Additionally, variable scale, and even social vs. political vs. ecological designation often overlap. For example, ‘region’ encompasses variations in geology, climate, soil development potential, invasive grass types, animal unit months (AUMs) supported, and number of national parks, to name a few. Region was an important association for many research questions (Appendix B: Q. 36-45).

As the Mojave Desert and Great Basin regions are ecologically distinct, we wanted to provide researchers with information directly addressing regional interest in their science results. Region was a significant predictor of willingness to assess BSC, value BSC soil stability, consider pollinators important, consider kangaroo rats a concern, be concerned about halogeton, and be interested in halogeton control (Table 3.3). Region was not significantly associated with general support of post-wildfire experimental treatments, fertile island research, or any small mammal actions including kangaroo rat specific questions. Great Basin managers were less likely to be interested in BSC assessments or pollinator-based seed selection and more likely to be concerned about, and request funding to control, halogeton. Respondents who work in the southern Great Basin were the most likely to consider kangaroo rats a concern, but were also more likely than other regions, though not significant, to think actions regarding kangaroo rat seed predation 'doesn't matter'; they were also more likely than other regions to think fertile island research 'doesn't matter' (also not significant).

The summary in Table 3.2a implies that while research value is associated with coarse-scale ecological variables, fine-scale ecological variables (e.g., livestock trade-off decisions) unrelated to other research presented were rarely associated with research response. However, the line between coarse- and fine-scale ecological variables is subjective, and some coarse-scale ecological preferences and opinions unrelated to

Table 3.3

Innovation adoption by region

Survey Question	Great Basin *N* = 172	Mojave Desert *N* = 58	Southern Great Basin *N* = 26	X2, DF, p-value
1) I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet. 'Agree' vs. 'Disagree'	83 v 4%	84 v 7%	67 v 17%	7.493, 6, 0.2776
2) When applying for funding post-wildfire, assessing Biological Soil Crust could help us assess hydrology and soil stability faster. vs. Our present methods are accurate and sufficient without assessing Biological Soil Crust.	55 v 45%	79 v 21%	39 v 61%	11.145, 2, 0.0038
3) Vegetation loss is a more reliable indicator of soil stability than Biological Soil Crust. 'Agree' vs. 'Disagree'	38 v 18%	27 v 24%	46 v 21%	9.751, 6, 0.1355*
4) Presence of fertile islands would influence how we reseed spatially. 'Absolutely' vs. 'Doesn't matter'	28 v 6%	28 v 3%	13 v 22%	12.23, 10, 0.2699
5) If a wildfire is patchy in nature, I would prioritize seed from species that are pollinated by specialist insects and let the wind-pollinated and less specialized species reseed on their own. 'Absolutely' vs. 'Doesn't matter'	13 v 12%	21 v 8%	22 v 39%	20.993, 10, 0.0211

*Notably BSC value for soil stability assessment was significant between Mojave Desert and Great Basin (X-squared = 8.295, df = 3, p-value = 0.0403), but was not significant between southern Great Basin and either other region (Great Basin vs. southern Great Basin: X-squared = 1.467, df = 3, p-value = 0.69; Mojave Desert vs. southern Great Basin: X-squared = 3.028, df = 3, p-value = 0.3874).

Table 3.3 continued

Survey Question	Great Basin *N* = 172	Mojave Desert *N* = 58	Southern Great Basin *N* = 26	X2, DF, p-value
1) Do you consider Kangaroo rats a nuisance species post-wildfire? ‘Always’+ ‘sometimes’ vs. ‘No’)	21% v 15%	14% v 35% (0 always)	17% v 22%	26.757, 8, 0.0008
2) Given these results, if Kangaroo rat density is high, would you increase your seeding density? ‘Absolutely’ vs. ‘Doesn’t matter’	12 v 28%	17 v 23%	19 v 29%	5.718, 8, 0.6788
3) Would you apply for funding to exclude or control Kangaroo rat density? ‘Absolutely’ vs. ‘Doesn’t matter’	8 v 26%	10 v 48%	10 v 57%	4.235, 8, 0.8353
4) I am concerned about halogeton post-wildfire. ‘Agree’ vs. ‘Disagree’	49 v 8%	26 v 14%	29 v 33%	26.994, 6, 0.0001
5) I typically request money for halogeton control post-wildfire. ‘Agree’ vs. ‘Disagree’	8 v 31%	6 v 20%	5 v 57%	15.476, 6, 0.0169
6) If small mammal abundance is high, I would request less money for halogeton herbicide treatments. ‘Agree’ vs. ‘Disagree’	15 v 15%	17 v 20%	10 v 10%	0.059, 2, 0.971
7) If small mammal density is high, I would request money to (Any action vs. ‘Doesn’t matter’)	70 v 30%	66 v 24%	84 v 16%	16.794, 14, 0.2673

climate risks (which were often associated with research response, as discussed below) were also associated with research responses.

Hypothesis 2: Personal climate and wildfire risks will influence attitudes to research.

The summary in Table 3.2a indicates that willingness to consider fertile islands in planning and overall support for incorporating experimental treatments into rehabilitation plans were most likely to be associated with personal wildfire experiences and perceptions of personal future wildfire risks (e.g., proximity of a wildfire potential area to manager's personal home). Overall, managers' personal wildfire experiences and risks were associated without about half of the research questions. Temperature risks were associated with about half of the research variables as well, and precipitation with one-third. Willingness to consider BSC, pollinator-based seed selection, and kangaroo rat density were more likely to be associated with climate risks. Fertile island research, halogeton concern and action, and small mammals-related research were not associated with climate opinions.

Hypothesis 3: Increased exposure to local norms and manager perceptions of local community attitudes will reflect manager attitudes to research.

Place exposure (increased exposure to local norms) variables were most numerous in association with BSC research and small mammals research (Table 3.2a). One or two local opinions and values were associated with each research presented (Table 3.2a and Table 3.4); manager interest in decreasing herbicide use based on small mammal abundance was associated with the most local values. Small mammals considerations and pollinator-based seed selection were least associated with social-political variables (five and one coarse-scale and four and two fine-scale respectively, Table 3.2a). In Table 3.4, those managers more likely to indicate willingness or ability to consider research presented were also more likely to think local communities disagree with most management decisions.

Hypothesis 4: Cost-time variables will influence manager attitudes to research. Cost-time barriers were directly addressed in four questions (Table 3.5, willing to consider research 'if we had the time,' 'if we had the money,' 'both') and indirectly assessed for all research related questions (time frame and funding questions' statistical association with research). Indirect cost-time barriers also included perceived interest group values, as interest group attitudes are likely to affect litigation and other types of pressures that take up costs and time for managers. Contrary to Wright's (2010) findings that time represented the greatest barrier to innovation, our study of specific research and direct cost-time variables often indicated money was more of a barrier than time alone (three out of 4 questions, Table 3.5). As few questions directly addressed cost-time considerations, more study on specific research trade-offs are needed. Indirect cost-time assessment found all three time frame and funding constraint questions were associated with general support for incorporating research, assessing soil stability via BSC vs. vegetation, halogeton concern, and halogeton control.

Manager perceptions that interest groups are concerned and think projects are crucial were more likely to be associated with manager ability or willingness to consider research (Table 3.6). Interest group pressures were associated with almost all specific research responses presented (exceptions pollinators and small mammal response);

Table 3.4
Local norms influence on manager innovation adoption

When managers are more likely to consider research:	**Perceived public post-wildfire project concern and opinions**		
	Local are concerned about post-wildfire projects	Locals agree with most decisions	Other social values associated
1) Support experimental post-wildfire treatments	Locals are concerned, Larger public is not concerned	Locals agree	
2) Our present methods are insufficient without Biological Soil Crust.			*Locals:* precise policy, naturally heal *Manager:* lived in region longer
3) Vegetation is a not better indicator of soil stability than Biological Soil Crust.	Locals are concerned	Locals disagree	
4) Presence of fertile islands would influence how we reseed spatially.	Larger public is concerned/Neutral	Locals disagree	
5) Would prioritize specialist pollinator seed.	Locals are not concerned		
6) Do consider Kangaroo rats a nuisance species post-wildfire.			*Locals:* policy doesn't fit, projects are crucial *Managers:* lived region longest
7) Would increase seeding density based on Kangaroo rat density.	Locals are not concerned	Locals disagree	
8) I would apply for funding to exclude or control Kangaroo rat if needed.			*Locals:* Policy doesn't fit
9) I am concerned about halogeton in my ecosystems.	Locals are not concerned Larger public is concerned	Locals disagree	
10) I do request money for halogeton control.	Locals are not concerned		
11) I would lessen halogeton herbicide based on small mammal abundance	Locals are concerned/neutral		*Locals:* precise policy, science-based projects *Managers:* lived in region 6-10 years
12) I would take some action regarding small mammals and seed predation			*Managers:* lived community longest

Table 3.5

Cost and time barriers influence on manager innovation adoption. Direct cost-time barriers were nested in survey questions, for example: pollinator-based seed selection ‘if we had the money’, if we had the time’, ‘if we had the money and the time’. Indirect cost-time barriers were identified through statistics association with proposal time frames and/or funding (e.g., Lack of funding for projects often cause changes to projects later on).

Managers unable/unwilling to incorporate research into post-wildfire treatments	Cost barrier: Indirect (Funding often causes later changes)	Cost barrier: Direct ‘If we had $’	Time barrier: Indirect 1. Proposal time frame 2. Time frame often causes later changes	Time barrier: Direct ‘If we had time’	Cost-time barrier: Direct ‘If we had $ and time’
1) Don’t support experimental post-wildfire treatments	X		XX		
2) Our present methods are sufficient without Biological Soil Crust.	X		0		
3) Vegetation is a better indicator of soil stability than Biological Soil Crust.	X		XX		
4) Presence of fertile islands would not influence how we reseed spatially.		14%	0	7%	17%
5) Would not prioritize specialist pollinator seed.	X	13%	X	12%	14%
6) Do not consider Kangaroo rats a nuisance species post-wildfire.			0		

Table 3.5 continued

Managers unable/unwilling to incorporate research into post-wildfire treatments	Cost barrier: Indirect (Funding often causes later changes)	Cost barrier: Direct 'If we had $'	Time barrier: Indirect 1. Proposal time frame 2. Time frame often causes later changes	Time barrier: Direct 'If we had time'	Cost-time barrier: Direct 'If we had $ and time'
1) Would not increase seeding density based on Kangaroo density.	X	46%	0	4%	9%
2) Would not exclude Kangaroo rats.		24%	0	6%	13%
3) Not concerned about halogeton.	X		XX		
4) Don't request money for halogeton control	X		XX		
5) Would not use less halogeton herbicide treatments based on small mammals #s			X		
6) Would not adjust methods even if many small mammals			0		

Table 3.6
Perceived interest group (IG) influence on manager innovation adoption

When Managers are more likely to consider research:	**Perceived interest group (IG) post-wildfire project concern and opinions**			
	Interest groups are concerned about post-wildfire projects	Interest groups think projects are crucial	Interest groups want precise policy followed	Interest groups want projects to be science-based
1) Support experimental post-wildfire treatments	IG are concerned			
Our present methods are insufficient without Biological Soil Crust.		IG: crucial	IG: precise policy unrealistic	
2) Vegetation is a not better indicator of soil stability than Biological Soil Crust.	IG are concerned	IG: crucial		IG: science unrealistic
3) Presence of fertile islands would influence how we reseed spatially.	IG are concerned	IG: crucial		
4) Would prioritize specialist pollinator seed.				
Do consider Kangaroo rats a nuisance species post-wildfire.	IG are not concerned	IG: naturally heal		IG: science-based
5) Would increase seeding density based on Kangaroo density.				IG: science unrealistic
6) I would apply for funding to exclude or control Kangaroo rat if needed.		IG: crucial		
7) I am concerned about halogeton in my ecosystems.		IG: crucial		
8) I do request money for halogeton control.			IG: precise policy unrealistic	
9) I would lessen halogeton herbicide based on small mammal abundance	IG are concerned		IG: precise policy unrealistic	
10) I would take some action regarding small mammals and seed predation				

however, managers thinking interest groups prefer precise policy was never associated with manager willingness to consider research presented.

Hypothesis 5: Coarse- and fine- social, political, and ecological variables will influence public land managers' and local communities' attitudes toward research.

As can be seen throughout the previous results and in Table 3.2a, coarse- and fine-scale variables in all categories were important both to manager valuation of experimental techniques in general, and specific research presented. For example, analysis identified a variety of coarse- and fine-scale social, political, and ecological variables associated with general support of experimental techniques (Figure 3.3): two (out of four) wildfire risk variables, six (out of 13) coarse-scale social-political variable (two related to interest group pressures), four (out of 21) fine-scale social-political variable (two related to place exposure), five (out of six) coarse-scale ecological variables (two of which were related to climate risks), and seven (out of 16) fine-scale ecological variables – all seven of which were research presented (Table 3.2a and Appendix B: Q. 35). Indirect cost and time variables (funding and time frames for proposal submission) were associated with less manager ability/willingness to incorporate experimental techniques into post-wildfire projects. However, policy, and even perceived interest group concern, were often associated with increased ability/willingness to incorporate experiments (Table 3.6 and Figure 3.3 and Appendix B: Q. 35). Ability/willingness to consider incorporating experimental techniques in post-wildfire projects was associated with increased climate and personal property wildfire risks (Table 3.2a). Managers willing to consider experiments were more likely to think local communities are concerned about post-wildfire projects and that they agree with management decisions overall (Table 3.5).

Indeed, while a smaller percentage of local respondents supported using experimental techniques overall compared to managers (81% managers Table 3.2a vs. 59% public, Table 3.2b), public respondents who did support experiments were more likely to agree with management decisions (X-squared = 39.029, df = 9, p-value = 1.138e-05) and prefer science-based post-wildfire projects (X-squared = 12.788, df = 3, p-value = 0.005118, Appendix C: Q. 28). Table 3.2b identifies the following categories important to public support of experiments: zero (out of four) wildfire variables, three (out of six) coarse-scale social-political variables (of which one = trust agencies), 11 (out of 27) fine-scale social-political (five of which were related to place exposure, out of 15), eight (out of eight) coarse-scale ecology variables (including both increased drought/ floods and temperature risks), and eight (out of 12) fine-scale ecology variable.

To summarize, all research variables were associated with coarse- and fine-scale social-political and ecological factors; fine-scale ecological variables and wildfire risk were the least likely to be related to research response for managers. Local communities' support of experimental research techniques were related to many variables, and nearly all ecology variables regardless of scale. Both public land managers and local community ability/willingness to consider experimental techniques of research was related to climate risks, but only land managers' ability/willingness was related to personal property wildfire risks.

Discussion

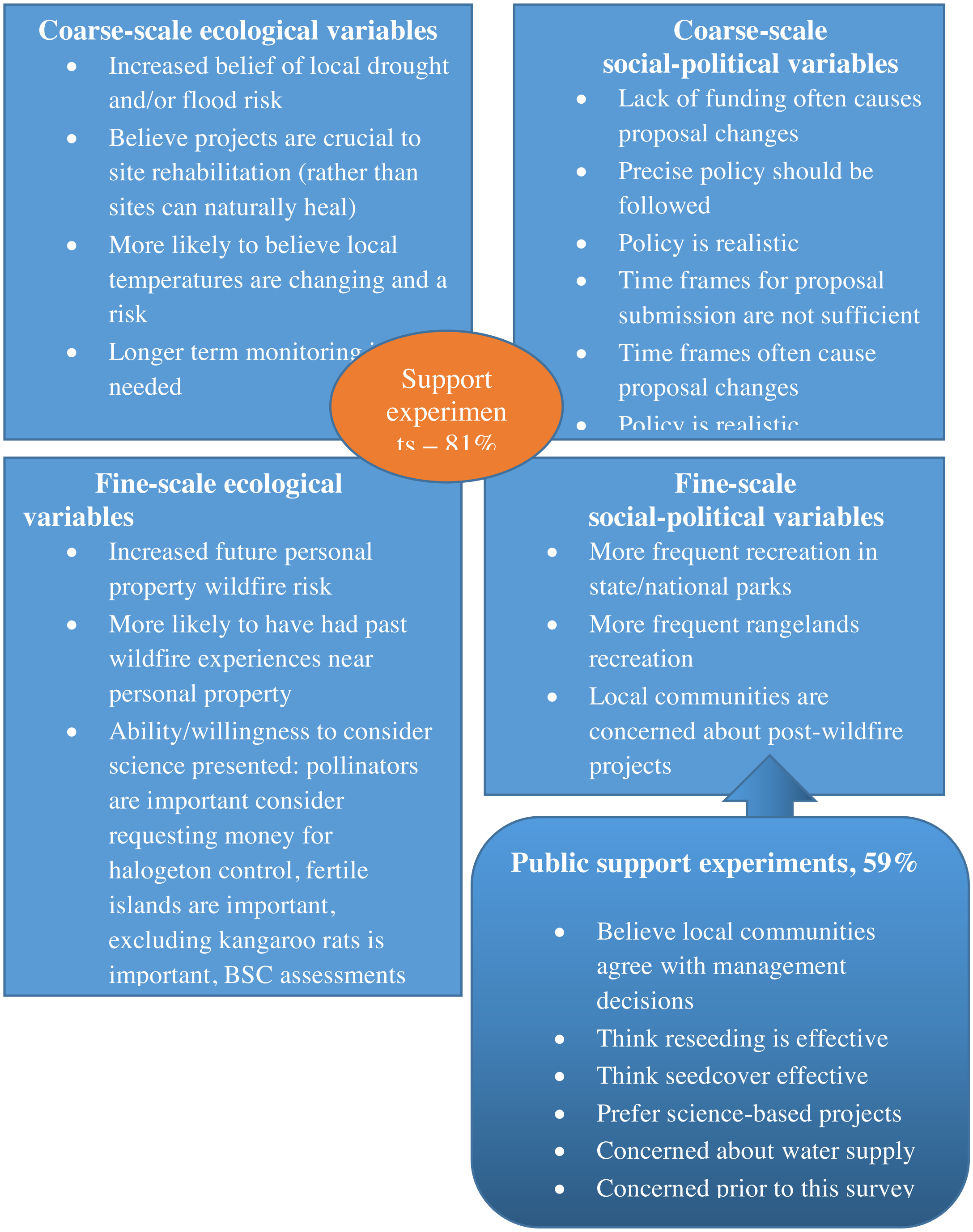
Innovation theory suggests that efficient diffusion of new science relies on facilitating positive attitudes toward the research. And yet this may be exactly where post-wildfire research is lacking. As Rogers (1964 p. 83) points out, for adoption to occur, an individual must have knowledge of the innovation, be interested in it, weigh the advantages and disadvantages (form attitudes), decide to implement it, actually implement it, and confirm the usefulness of the new practice. Each of these steps likely require outside assistance for time-constrained post-wildfire managers, such as research synthesis (Kearns and Wright 2002; Wright 2004) and realistic cost-benefit analyses, yet these are rarely provided in scientific journal articles or at conferences.

Both research and logic suggest it is unrealistic for post-wildfire rehabilitation projects to be solely based on ecological variables (Wright 2010). However, a sort of ecologically rooted idealism was reflected in conflicting results regarding project visibility and political pressure prioritization. In semi-structured interviews, visibility of sites and public and political pressure were mentioned as important factors in site selection (Chapter 2); however, in the structured surveys, nearly all managers prioritized more severely degraded post-wildfire sites regardless of visibility or political pressure. These conflicting results were likely due to phrasing, managers selecting their ideal vs. real world scenarios. Nonetheless, collaboration research suggests projects that acknowledge social contexts may be more resilient than those based solely on environmental considerations (Daniels and Walker 1996). More visible sites may also garner more support for projects in general (Cabin 2007; Palmer et al. 2007; Manning 2009).

In addition to ignoring social resilience, it is probably unrealistic to believe most project successes in the Anthropocene Epoch (a term that describes the pervasive and profound nature of human activities on all aspects, including geology, of the natural world, Steffen et al. 2007) can be determined solely by ecological variables. Furthermore, this study confirms post-wildfire managers' ability/willingness to consider new research is not solely associated with ecological variables, even when associated ecological variables are numerous (Fig. 3.3); social and political attitudes and values (including perceived behavioral control variables such as cost and time) were all influential components to science uptake. And yet, post-wildfire ecological modeling tends to avoid non-ecological variables or incorporate very few social variables (Meinke et al. 2009; Pyke 2011; Arkle et al. 2014; Knutson et al. 2014).

Respondent Characteristics, Wildfire Risk, Climate Risks, and Place Exposure

Effectively diffusing new science is likely dependent on the characteristics of early-adopters (Wright 2004). In 2010 Wright found some identifiers of early adopters: employees with higher pay grades, longer-term fire analysts, NPS managers, and managers with Master's degrees were more likely to represent early innovators. Our results suggested slightly different individual-level influences on diffusion of specific, rather than general, innovation. We found longer tenure to be important to innovation in general. Managers solely responsible for data collection (rather than any proposal writing) were more likely to be interested in BSC and concerned about halogeton.



Coarse-scale ecological variables

- Increased belief of local drought and/or flood risk
- Believe projects are crucial to site rehabilitation (rather than sites can naturally heal)
- More likely to believe local temperatures are changing and a risk
- Longer term monitoring i needed

Coarse-scale social-political variables

- Lack of funding often causes proposal changes
- Precise policy should be followed
- Policy is realistic
- Time frames for proposal submission are not sufficient
- Time frames often cause proposal changes
- Policy is realistic

Support experimen ts – 81%

Fine-scale ecological variables

- Increased future personal property wildfire risk
- More likely to have had past wildfire experiences near personal property
- Ability/willingness to consider science presented: pollinators are important consider requesting money for halogeton control, fertile islands are important, excluding kangaroo rats is important, BSC assessments

Fine-scale social-political variables

- More frequent recreation in state/national parks
- More frequent rangelands recreation
- Local communities are concerned about post-wildfire projects

Public support experiments, 59%

- Believe local communities agree with management decisions
- Think reseeding is effective
- Think seedcover effective
- Prefer science-based projects
- Concerned about water supply
- Concerned prior to this survey

Fig. 3.3. Experimental research multi-scalar model. Responses to the statement, "I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet." Coarse- and fine-scale social, political, and ecological variables associated with manager innovation potential post-wildfire.

Additionally, managers with ‘fire’ in their job title were less willing to consider changing behavior based on research implications. This last detail supports the concept that tight time frames involved with post-wildfire may hinder innovation diffusion. Considering the increasing acres treated though federal post-wildfire rehabilitation, this translates to vast areas where best management practices stagnate into “practice attachment.”

Overall, contrary to public wildfire risk findings (McCaffrey et al. 2011), personal wildfire experience and perceived wildfire risks were not often associated with manager ability/willingness to consider specific research (Table 3.2a). For those variables not associated with personal wildfire risks and considered unimportant by many managers (e.g., excluding kangaroo rats), this may suggest the value (relative advantage, observability) of post-wildfire research presented was not high. Notably, the general concept of incorporating experimental techniques as well as fertile island accommodation were most likely to be associated with personal wildfire risks (Table 3.2a). Fertile island accommodation also garnered some of the most manager consideration (Table 3.1); fertile islands are more directly and easily associated with wildfire than, for example, kangaroo rat seed predation (in other words, less complex per Rogers 1995). These results indicate many post-wildfire managers do not have the capacity to use research, and so are unable to consider or pay attention to it. Highlighting wildfire relevance of research earlier in publications and conferences may assist research diffusion to managers.

Beliefs about long-term changes in temperature and precipitation currently remain contentious in many agencies and are influenced by social, political, and ecological ideologies (Whitcomb 2011). Regional model forecasts for the Great Basin and Mojave

Desert suggest these areas will experience increases in temperature (which increase evapotranspiration rates) and changes in precipitation timing, intensity, duration, and totals (Wagner 2003; IPCC 2013; Anderegg and Diffenbaugh 2015). Both increased temperature and precipitation changes affect plant-available water for native plants already highly specialized to past climate conditions (Svejcar et al. 2003; Hatfield et al. 2008). The majority of managers were concerned about precipitation event risks (e.g., droughts and floods, we did not ask if they felt these events are changing in frequency, severity, etc.). Despite overwhelming scientific consensus predicting increasing temperatures in these regions, managers responding to the survey remained uncertain about temperature changes. Part of this uncertainty may be related to a lack of perceived control, as defined in the Theory of Planned Behavior (Ajzen 1991). Previous studies have indicated even managers who agree climate changes are occurring were unsure how to alter management practices to cope with these changes (Whitcomb 2011). Rehabilitation proposals mainly acknowledge potential impacts of climate change, but do not often suggest on the ground strategies (Zahniser et al. 2009). Perceptions of climate risks were associated with several research areas including overall ability/willingness to incorporate experimental techniques into post-wildfire projects. To assist managers' perceived control regarding climate adaptation, researchers can highlight temperature and precipitation related feedbacks of their research topics (local, regional, and/or global).

Subjective norms can influence attitudes toward a behavior (Hovland et al. 1953, Ajzen and Fishbein 2005); one approach to understanding land manager subjective norm influence has been capture theory. Capture theory is fairly controversial, however, because it tends to cast community involvement in a negative light. This is contrary to the goals of translational ecology. Additionally, at least one place-exposure variable (e.g., years lived in community) was associated with nearly every research area presented (Table 3.2a), sometimes supporting consideration of new research, sometimes not (Appendix B: Q. 36-45). More frequent recreation in state/national parks and multiple-use rangelands, when associated with research, tended to predict the most ability/ willingness to consider new research. This suggests variables related to this concept of increased place exposure or capture (e.g., longer time lived in the community), do not always result in "negative capture," and may even support manager consideration of new research in some scenarios.

Effect of Stakeholder Involvement/ Opinions on Manager Responses to Research

Direct local pressures (local concern and agreement) were associated with increased ability/willingness to consider experimental techniques in rehabilitation plans. Additionally, one or two local variables were associated with each of the more specific research areas presented (Table 3.2a), suggesting local norms likely influence manager interest in new research. While living and recreating in a place tended to support research (Appendix B: Q. 36-45), manager's that were more able/willing to consider new research were more likely to also think locals disagree with most management decisions. This could either reflect a perceived barrier to adoption, or, it could also be imagined managers were more interested in research because of perceived public discontent with current management decisions. Similarly, when managers believed interest groups are concerned about projects, they were more likely to support the use of research both generally and specifically. This may seem surprising given the barriers associated with interest group involvement in Chapter 2. It is possible that managers may believe new research is attractive to interest groups, where innovation can be a leverage for mollifying concerned parties and finding a way forward.

Local community trust in land management agencies has been a historically difficult aspect of land management projects (Shindler et al. 2002; Shindler and Toman 2003; Gordon and Baldwin-Phillipi 2014); progress here in any capacity is encouraging. In the public survey presented here, all variables that could be related to trust in the public survey were associated with public support of science-based management (Chapter 2). Trust of agencies and belief that current methods are effective was also related to public respondents' willingness to support experimental techniques. As this study has indicated that local involvement and attitudes can impact post-wildfire manager ability/willingness to consider new science, researchers and agencies should actively address local opinions and concerns before implementing a new strategy. Additionally, environmental interest groups arose from a political organization and litigation contexts (Berry 2015); interest group involvement and leverage tend to increase when local and regional trust is eroded. Directly addressing trust by actively creating dialogue with interest groups and local communities has been shown to provide opportunities for projects moving forward rather than create litigation barriers (Daniels and Walker 1996).

Examples of effective translational restoration approaches are beginning to emerge. Toledo et al. (2012) found that Prescribed Burn Associations (PBAs) that engage landowners as well as agencies helped alleviate subjective norms as well as strengthened trust with land agencies. Collaborative partnerships also increased positive experiences with new treatments (Toledo et al. 2013), decreased risk perceptions related to innovations, increased ideas of self-efficacy (Toledo et al. 2012), improved trust in the group members and agencies (Lister et al. 2012), and increased cooperation across ecologically relevant scales that exceed political boundaries (Toledo et al. 2014). Ethical appeals, such as discussing and writing down shared goals, can also result in cooperative innovation experiments that reduce costs to the individual agency or landowner and may experience longer-term commitments (Lister et al. 2012). Collaborations are a form of social innovation, especially for time-constrained post-wildfire projects. Social innovations may face some of the largest barriers to post-wildfire innovation adoption, as they may not incorporate easily into existing post-wildfire frameworks (e.g., developing common ground strategies prior to the start of a project). Meetings cost money to organize and run. Additionally, decision makers might have to overcome individual psychological characteristics (e.g, social anxiety) to become involved in collaborations. Similarly, scientific conferences, while incorporating information flow through feedback question and answer sessions, often present new techniques in ways that don't address land manager concerns (e.g., policy feasibility, self-efficacy, costs). Including translational workshops at conferences may be an important step to collaborative and effective science delivery between researchers and managers.

Cost, Time, and Value Lens

The importance of social, political, and ecological, and cost-time-value factors varied based on specific research presented. Nonetheless, it is likely important to address time and cost barriers for all variables, when trying to ensure best management practices according to new science. Funding was identified in semi-structured interviews (Chapter 2) as a major barrier to project implementation. In structured manager surveys, 68% of managers (*n* = 231) said they do not receive the amount of funding requested for at least half of their projects and must subsequently make adjustments to their initial proposals (compared to 10% never or rarely a concern). Simultaneously, federal funds to fight wildfires are decreasing (Week 2013) and concerns are growing about whether these funds will be replenished. Indeed, in Nevada in 2013, one rehabilitation project received not even a third of the requested funds for recommended site rehabilitation (Delong 2013). Funding can mean the difference between letting an area naturally regenerate and being able to use a more expensive, but more appropriate tool. Collaborations may provide opportunities for multiple sources of funding (local coalitions, interest groups, research institutions). Managers attempting to incorporate new science without collaborations likely need restoration methods and new innovations to be extremely low cost and high benefit (decreasing the amount of innovations compatible).

Values of research are context-dependent: they vary in each community and post-wildfire situation. This study indicates that social-political values and pressures are important considerations for new science uptake. Summarizing costs and benefits of an innovation in publications directed for post-wildfire managers is likely a critical step for researchers attempting to increase innovation diffusion.

In this study we suggest costs of new research, time to incorporate new research, and value of the research will be foremost in predicting diffusion or research results into actual land management. Yet publications rarely provide managers with this type of information. We also make the argument collaborations, even in post-wildfire situations, may be instrumental to the social-ecological resilience of the Great Basin and Mojave Desert. Following is an example of how cost-time-value assessments can be summarized for managers, in this case with regards to post-wildfire collaborations:

- Benefits to managers: Potential to decrease appeals and litigation, improve trust and procedural justice, decrease public risk perceptions of specific treatments, increase long-term monitoring opportunities through local engagement, and provide opportunities for multiple funding sources (local coalitions, interest groups, and research institutions).
- Benefits to researchers: Address barriers managers may face to implementation, informally assess value of specific research, increase feedback, decrease costs by facilitating multiple funding sources, open avenues for citizen science projects, improve public science opinion.
- Costs: Meeting announcements, venue reservation (ideally in the winter before fire season and directly following and/or during a fire), food and drinks, cost of personnel time, possible mitigation specialist hiring in high conflict areas, gas and vehicle use for meetings and to access visits to sites. Repeat costs at specified intervals (post-fire, 3 months, 6 months, 9 months, yearly).
- Barriers: Individual manager and group participant characteristics (e.g., social anxiety), distrust, disbelief collaboration will be effective (group-efficacy), perceived low ratio time:benefit trade-off (self-efficacy), “practice attachment” of public and/or managers, and lack of concern/interest (public and land managers).

Implications

New science adoption in post-wildfire situations is subject to many barriers. Social science theory as well as the results of this study suggest common themes critical to encouraging post-wildfire innovation adoption. Creating collaborative associations prior to wildfires, if possible, is likely to social-ecological resilience. Researchers may be able to diffuse new science faster by summarizing cost-time-value information. Post-wildfire managers' willingness and ability to consider the specific science results of collaborating researchers represents a unique effort in advancing translational post-wildfire science between university researchers and post-wildfire managers.

References

Ajzen, I, 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179-211.

Ajzen, I, Fishbein, M, 2005. The influence of attitudes on behavior. The handbook of attitudes, 173, 221.

Anderegg, WR, Diffenbaugh, NS, 2015. Observed and projected climate trends and hotspots across the National Ecological Observatory Network regions. Frontiers in Ecology and the Environment, 13(10), 547-552.

Arkle, RS, Pilliod, DS, Hanser, SE, Brooks, ML, Chambers, JC, Grace, JB, Wirth, TA, 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere, 5(3), 31.

Barney, DR, Nader, R, 1974. The Last Stand. Grossman Publishers, City, State, 185 pp.

Berry, JM, 2015. Lobbying for the people: The political behavior of public interest groups. Princeton University Press.

Breiman, L, Cutler, A, 2007. Random Forest Available at: http://www.stat.berkeley.edu/~breiman/RandomForests/cc_home.htm (Accessed 12 December 2015)

Bruce, MC, Newingham, BA, Harris, CC, Krumpe, EE, 2014. Opinions toward using volunteers in ecological restoration: a survey of federal land managers. Restoration Ecology, 22(1), 5-12

Brunson, MW, 2012. The elusive promise of social-ecological approaches to rangeland management. Rangeland Ecology and Management, 65(6), 632-637

Brunson, MW, 2014. Unwanted no more: land use, ecosystem services, and opportunities for resilience in human-influenced shrublands. Rangelands 36(2), 5-11.

Brunson, MW, Baker, MA, 2015. Translational training for tomorrow's environmental scientists. Journal of Environmental Studies and Sciences, 1-5.

Brussard, PF, Charlet, DA, Dobkin, DS, Ball, LC, Bishop, KA, Britten, HB, Fleishman, E, Fleury, SS, Jenni, T, Kennedy, TB, Mullen, CO, 1998. Great Basin-Mojave Desert region. Status and trends of the nation's biological resources. US Geological Survey, 2.

Cabin, RJ, 2007. Science-Driven Restoration: A Square Grid on a Round Earth?. Restoration Ecology, 15(1), 1-7. Cortner, HJ, Wallace, MG, Burke, S, Moote, MA, 1998. Institutions matter: the need to address the institutional challenges of ecosystem management. Landscape and Urban Planning, 40(1), 159-166.

Culhane, PJ, 2013. Public lands politics: Interest group influence on the Forest Service and the Bureau of Land Management. Routledge.

Cutler, DR, Edwards, TC, Beard, KH, Cutler, A, Hess, KT, Gibson, JC, Lawler, JJ, 2007. Random forests for classification in ecology. Ecology 88(11), 2783-2792.

Daniels, SE, Walker, GB, 1996. Collaborative learning: improving public deliberation in ecosystem-based management. Environmental impact assessment review, 16(2), 71-102.

Delong, J, 2013. Rehab for just third of land burned by Bison Fire. Available at: http://www.rgj.com/article/20130902/NEWS06/309020017/Rehab-just-third-land-burned-by-Bison-Fire-Northern-Nevada (Accessed 03 April 2015)

Dillman, DA, 2007. Mail and Internet surveys: the tailored design, second edition-2007 update. New York: John Wiley. 565 pp.

Federal Clean Water Act, 1977. 33 U.S.C. 1288 and P.L. 95-217. The Soil and Water Resources Conservation Act of 1977 (P.L. 95-192). Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/about/history/?cid=nrcs143_021392 (Accessed 11 December 2015).

Fox, RJ, Crask, MR, Kim, J, 1988. Mail survey response rate a meta-analysis of selected techniques for inducing response. Public Opinion Quarterly, 52(4), 467-491.

Germain, R, Floyd, D, Stehman, S, 2001. Public perceptions of the USDA Forest Service public participation process. Forest Policy and Economics 3, 113–124.

Google Earth (Map data ©2016 Google)

Gordon, E, Baldwin-Philippi, J, 2014. Playful civic learning: enabling lateral trust and reflection in game-based public participation. International Journal of Communication, 8, 28.

Hatfield, J, Boote, K, Fay, P, Hahn, L, Izaurralde, C, Kimball, BA, Mader, T, Morgan, J, Ort, D, Polley, W, Thomson, A, Wolfe, D, 2008. Agriculture. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC, USA. 362 pp.

Heberlein, TA, Baumgartner, R, 1978. Factors affecting response rates to mailed questionnaires: A quantitative analysis of the published literature. American Sociological Review, 447-462.

Hovland, CI, Janis, IL, Kelley, HH, 1953. Communication and persuasion. Yale University Press. New Haven, CT. 315 pp.

Intergovernmental Panel on Climate Change (IPCC), 2013. Annex I: atlas of global and regional climate projections. In: Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Jantarasami, LC, Lawler, JJ, Thomas, CW, 2010. Institutional barriers to climate change adaptation in US national parks and forests. Ecology and Society, 15(4), p.33.

Kearns, S, Wright, V, 2002. Barriers to the use of science: U.S. Forest Service case study on fire, weed, and recreation management in wilderness. Unpublished Report. 70 p. On file at: Leopold Institute, P.O. Box 8089, Missoula, MT 59807.

Knutson, KC, Pyke, DA, Wirth, TA, Arkle, RS, Pilliod, DS, Brooks, ML, Chambers, JC, Grace, JB, 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. Journal of Applied Ecology, 51(5), 1414-1424.

Lister, R, Smith, P, Torrez, S, Baker, S, 2012. Innovative partnership formed to restore the West Potrillos. Rangelands, 34(4), 31-34.

Madsen, MD, Kostka, SJ, Inouye, AL, Zvirzdin, DL, 2012. Postfire restoration of soil hydrology and wildland vegetation using surfactant seed coating technology. Rangeland Ecology & Management, 65(3), 253-259.

Manning, C, 2009. The psychology of sustainable behavior: Tips for empowering people to take environmentally positive action. Minnesota Pollution Control Agency.

McCaffrey, SM, Stidham, M, Toman, E, Shindler, B, 2011. Outreach programs, peer pressure, and common sense: what motivates homeowners to mitigate wildfire risk?. Environmental Management, 48(3), pp.475-488.

Meinke, CW, Knick, ST, Pyke, DA, 2009. A spatial model to prioritize sagebrush landscapes in the Intermountain West (USA) for restoration. Restoration Ecology 17(5):652-659.

Kursa, MB, Rudnicki, WR, 2010. Feature Selection with the Boruta Package. Journal of Statistical Software, 36(11), 1-13. Available at: http://www.jstatsoft.org/v36/i11/ (Accessed 18 August 2013).

Moote, MA, McClaran, MP, Chickering, D, 1997. Theory in practice: applying participatory democracy theory to public land planning. Environ Manag 21(6):877–889

O'Donnell, RP, Supp, SR, Cobbold, SM, 2010. Hindrance of conservation biology by delays in the submission of manuscripts. Conservation Biology, 24(2), pp.615-620.

Palmer, M, Allan, JD, Meyer, J, Bernhardt, ES, 2007. River restoration in the twenty-first century: data and experiential knowledge to inform future efforts. Restoration Ecology, 15(3), 472-481.

Pannell, DJ, Marshall, GR, Barr, N, Curtis, A, Vanclay, F, Wilkinson, R, 2006. Understanding and promoting adoption of conservation practices by rural landholders. Animal Production Science, 46(11), pp.1407-1424.

Pilliod, DS, Welty, JL, 2013. Land treatment digital library. U.S. Geological Survey Data Series 806. http://dx.doi.org/10.3133/ds806 PRISM Climate Group. 2011. Gridded climate.

Pyke, DA, 2011. Restoring and rehabilitating sagebrush habitats. In: Knick, ST, Connelly, JW (Eds.) Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology, University, 38, 531–548

R Development Core Team (R), 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org. (Accessed 29 Mar 2016).

Renn, O, Webler, T, Wiedemann, P, 1995. Fairness and competence in citizen participation: evaluating models for environmental discourse. Kluwer Academic, Boston.

Rogers, EM, 1964. Diffusion of Innovations, The Free Press, New York, NY.

Rogers, EM, 1995. Diffusion of innovations, 4th ed. The Free Press, New York, NY.

Rogers, EM, 2003. Diffusion of innovations, 5th ed. The Free Press. New York, NY.

Rowe, G, Frewer, LJ, 2000. Public participation methods. An evaluative review of the literature. Science, Technology and Human Values, 25, 3-29.

Schlesinger, WH, 2010. Translational ecology. Science, 329(5992), 609.

Society for Ecological Restoration (SER) International Science and Policy Working Group, 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, Tucson, Arizona.

Shackley, S, Deanwood, R, 2002. Stakeholder perceptions of climate change impacts at the regional scale: implications for the effectiveness of regional and local responses. Journal of Environmental Planning and Management, 45, 381-402.

Shindler, B, Brunson, MW, Stankey, GH, 2002. Social acceptability of forest conditions and management practices: a problem analysis. Environment and Society Department (ENVS) Faculty Publications, Utah State University, Logan, UT.

Shindler, B, Toman, E, 2003. Fuel reduction strategies in forest communities: A longitudinal analysis of public support. Journal of Forestry 101(6), 8–16.

Skinner, BF, 1953. Science and Human Behavior. Macmillan, New York, New York.

Steffen, W, Crutzen, PJ, McNeill, JR, 2007. The Anthropocene: are humans now overwhelming the great forces of nature. AMBIO: A Journal of the Human Environment, 36(8), 614-621.

SurveyMonkey, Inc. Whitcomb, H. Post-wildfire Policy and Practice, http://www.surveymonkey.com/s/ (last visited Oct. 8 2013) Company: SurveyMonkey Inc. Location: Palo Alto, California, USA

Survey Sampling International (SSI®)

Svejcar, AJ, Bates, JD, Angell, RF, Miller, RF, 2003. The influence of precipitation timing on the Sagebrush Steppe ecosystem. In: McPherson, G, Weltzin, J, (Eds.), Changing precipitation regimes & terrestrial ecosystems, Tucson, AZ, USA: University of Arizona Press, pp. 90-106.

Thomas, CW, 2003. Bureaucratic landscapes: interagency cooperation and the preservation of biodiversity. Massachusetts Institute of Technology Press, Cambridge, Massachusetts, USA.

Toledo, D, Kreuter, UP, Sorice, MG, Taylor Jr., CA, 2012. To burn or not to burn: ecological restoration, liability concerns, and the role of prescribed burning associations. Rangelands, 34(2), 18-23.

Toledo D, Kreuter UP, Sorice, MG, Taylor Jr., CA, 2014. The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems. Journal of Environmental Management, 132, 323-328

Toledo, D, Sorice, MG, Kreuter, UP, 2013. Social and ecological factors influencing attitudes toward the application of high-intensity prescribed burns to restore fire adapted grassland ecosystems. Ecology and Society, 18(4), 9.

United States Department of Agriculture (USDA) and United States Department of the Interior (USDI), 2003. Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy. 57 p. Available: http://www.nwcg.gov/branches/ppm/fpc/archives/fire_policy/index.htm (Accessed 15 March 2017).

United States Forest Service (USFS), 2012. National Best Management Practices for Water Quality Management on National Forest System Lands Volume 1: National Core BMP Technical Guide. FS-990a. Available at: http://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf (Accessed 15 March 2017).

USFS, Rocky Mountain Research Station (RMRS), 2004. Fuels planning: science synthesis and integration; forest structure and fire hazard fact sheet 05: fuel treatment principles for complex landscapes. Res. Note RMRS-RN-22-5-WWW. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2 p.

US Government Accountability Office (GAO), 2003. Wildland fires. GAO-03-430.

US GAO, 2006. Wildland fire rehabilitation and restoration. GAO-06-670.

Wagner, FH, 2003. Preparing for a changing climate – the potential consequences of climate variability and change. A report of the Rocky Mountain/Great Basin Regional Assessment Team for the U.S. Global Change Research Program. Logan, UT, USA: Utah State University. 240 pp.

Week, L, 2013. California wildfires further strain federal budget. Retrieved April 03, 2015, from http://money.cnn.com/2013/08/27/news/economy/wildfires-budget/index.html

Whitcomb, HL, 2011. Temperature increase effects on sagebrush ecosystem forbs: experimental evidence and range manager perspectives. All Graduate Theses and Dissertations. Paper 1044. Available at: http://digitalcommons.usu.edu/etd/1044 (Accessed 16 March 2017).

Wright, V, 2004. How do land managers adopt scientific knowledge and technology? Contribution of the Diffusion of Innovations theory. In: Munro, N, Dearden, P, Herman, TB, Beazley, K, Bondrup-Nielson, S, (Eds). Making Ecosystem-based management work. Proceedings of the Fifth International Conference on Science and Management of Protected Areas, Victoria, BC, 11-16 May 2003.

Wright, V, 2007. Communication barriers to applying federal research in support of land management in the United States. In: Miner, C, Jacobs, R, Dykstra, D, Bittner, B, (Eds.), General Technical Report PNW-GTR-726. Portland, OR: USDA Forest Service, Pacific Northwest Research Station, pp. 55-62.

Wright, V, 2010. Influences to the success of fire science delivery: perspectives of potential fire/fuels science users. USDA Forest Service, Rocky Mountain Research Station, Final Report to the Joint Fire Science Program, JFSP Project, pp.04-4.

Zahniser, A, Cossa, J, Stewart, S, 2009. BLM National Land Use Planning Conference "Keeping Pace with Change" Portland, OR. Available online at: http://www.blm.gov/pgdata/etc/medialib/blm/wo/Planning_and_Renewable_Resources/presentations.Par.2279 (Accessed 31 May 2016).

CHAPTER 4

BIOLOGICAL SOIL CRUST EFFECT ON COMMON RESTORATION GRASS AND FORB ESTABLISHMENT UNDER DIFFERENT SEEDING SIMULATIONS: A PILOT GREENHOUSE STUDY

Abstract

Biological soil crusts (BSCs) are an important ecological component of Great Basin ecosystems. Their presence can assist recovery after wildfire, yet BSC status is rarely a consideration in post-wildfire rehabilitation. In surveys, managers seem somewhat interested in BSC status, yet are unlikely to change seeding strategies. We designed a pilot greenhouse study examining interaction between seeding method and BSC successional group on establishment of native Great Basin grasses and forbs. Five groups were defined: minimal crust development [M1], early cyanobacteria [M2], mid-cyanobacteria/early mosses [M3], most developed crust diverse moss/lichen [M4], and non-successional tall-moss mats [M5]. BSCs were harvested from western Utah and lightly burned using a heat lamp. Three seeding methods were simulated: range drilling, minimum-till drilling, and broadcasting. Four native grasses and two native forbs commonly used in restoration were seeded: bluebunch wheatgrass (*Pseudoroegneria spicata*), bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), needle-and-threadgrass (*Hesperostipa comata*), western yarrow (*Achilea millefolium* L. var. *occidentalis*), and gooseberry globemallow (*Sphaeralcea grossulariifolia*), as well as the cool-season invasive annual grass, cheatgrass (*Bromus tectorum*). Even when lightly burned, BSC development and seeding treatment had significant effects on native plant establishment. More developed BSC supported greater emergence across native species; however, burning BSC resulted in no significant inhibitory effect on cheatgrass emergence (under greenhouse conditions). The non-successional tall-moss was often an emergence barrier for all species, but also supported visibly larger plants and increased survival once established; as tall-moss mats thrive under shrubs, they likely contribute to shrub fertile-island effect. We found BSC group may have more of an effect on plants when broadcast seeding or standard drilling; BSC development seemed to be less important under simulated minimum till drilling treatment. Overall this pilot study suggests BSCs may interact with seeding strategy, potentially impacting outcomes of some common restoration species; follow-up field studies are recommended.

Keywords: Drill seeding, Great Basin, biological soil crust, cheatgrass

Introduction

Semi-arid and arid landscapes have proven extremely difficult to restore, particularly when certain thresholds, such as percent cover of invasive species, are crossed (Knapp 1996). Invasive species in the Great Basin have created changes in disturbance regimes, soil legacies, and ecosystem hydrology (Rau et al. 2007). These changes can have vast and diverse effects on biotic interactions (Davies et al. 2012; Brooks et al. 2015) and ecosystem services (Graaf et al. 2015). Of particular concern in the Great Basin, the invasion of the cool-season annual grass *Bromus tectorum* L. (cheatgrass or downy brome) has resulted in a positive feedback relationship with wildfire (Pechanec and Hull 1945; Whisenant 1990). Cheatgrass, with its high reproductive output, often rapidly becomes a dominant vegetative characteristic in landscapes. As a cool-season annual grass, the cheatgrass lifecycle ends early in the summer, creating a large, dry, fine-fuels load. After a fire, the species readily takes advantage of disturbed landscapes, quickly becoming even more dominant. This process results in frequent fire return intervals and does not allow natural regeneration of long-lived perennial bushes, such as sagebrush. Over time landscapes can transition into a new state, cheatgrass monocultures, which are very difficult to restore. Recent research seems to indicate past restoration practices may have minimal impact in the short-term (< 20 years) for reducing cheatgrass (Arkle et al. 2014; Knutson et al. 2014).

Soil properties may contribute to the success or failure of some restorations (Rau et al. 2014). Biological soil crusts (BSCs) are communities of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria that inhabit semi-arid and arid ecosystems worldwide (Belnap and Eldridge 2003). These complex communities colonize the top few millimeters of soil, binding and stabilizing soil particles (Cameron 1966; Friedmann and Galun 1974; Friedmann and Ocampo-Paus 1976; Anderson, Harper and Holmgren 1982; Belnap and Gardner 1993; St. Clair and Johansen 1993; Warren 2001; Belnap and Eldridge 2003; Chaudhary et al. 2009), affecting soil properties and nutrient cycling (Harper and Marble 1988; Johansen 1993; Evans and Johansen 1999; Harper and Belnap 2001), occupying niches otherwise avoided by native plants (Belnap and Eldridge 2003) while also providing seed and seedling microsites (St. Clair et al. 1984; Harper and Marble 1988; Belnap et al. 2001), and altering water runoff patterns, infiltration (Maestre et al. 2002), and retention (Brotherson and Rushforth 1983; Campbell et al. 1989; Gold and Bliss 1995; Fierer and Gabet 2002). BSCs represent an integral component of many landscapes and can be used as indicators of rangeland health (Pellant et al. 2000; Tongway and Hindley 2000).

While intact BSCs benefit most plants through increased nutrient and water availability, some studies have suggested native North American species may be better equipped to access these resources than non-natives. Native species often have specialized root penetration ability (Dienes et al. 2007) and/or seed self-burial (Stamp 1984; Larsen 1995; Howell 1998; Belnap et al. 2003). Some non-natives are less adept at self-burial (Hernandez and Sandquist 2011), subjecting seeds to greater risk of desiccation or predation (Stohlgren et al. 2001; Morgan 2006). Non-native seeds also tend to be more visible to predators on intact crusts and more camouflaged on disturbed crusts relative to native seeds (Hernandez and Sandquist 2011). Finally, BSCs may inhibit non-native seeds from establishing by altering soil pH or producing secondary compounds (Garcia-Pichel and Belnap 1996; Belnap et al. 2003). Indeed, studies have demonstrated that BSCs can inhibit the establishment of cheatgrass (Larsen 1995; Howell 1998; Serpe et al. 2006; Dienes et al. 2007) and other noxious weeds (Hernandez and Sandquist 2011), while facilitating or having no effect on many native annual grasses and perennial forbs (St. Clair et al. 1984; Harper and St. Clair 1985; Eckert et al. 1986; Larsen 1995; Howell 1998; Bashkin et al. 2003; Hernandez and Sandquist 2011). Since BSCs exist in arid and semi-arid deserts worldwide, including where cheatgrass is native, BSC inhibition of cheatgrass may partially explain this species' evolutionary need of a high reproductive output. Conversely, from a plant community perspective, BSC presence is positively correlated with native species richness and cover (Kleiner and Harper 1977; Jeffries and Klopatek 1987).

Fire inevitably decreases BSC biomass, cover, diversity (Johansen et al. 1982, 1984; Johansen 1993; Hilty et al. 2004), and ecosystem services (Johansen et al. 1998). However, BSC components exhibit some resistance (minimal change in structure or function) to fire. Johansen (2001) demonstrated that large filamentous cyanobacteria had moderate resistance, whereas lichens and mosses were the least resistant. Additionally, native grassland wildfires and prescribed fires may not generate enough heat to eliminate or harm BSCs (Johansen 2001; Bowker et al. 2004; Warren et al. 2015). Dead cyanobacterial sheath material can hold particles together, aggregating soil and reducing dust production (Belnap 2006). Overall, BSCs seem able to resist and/or rebound fairly well from most fires in healthy systems.

When BSCs are disturbed there is a temporary pulse of resources, such as increased availability of soil nitrogen (Larsen 1995; Howell 1998). However, disturbance of BSCs results in loss of structural and possibly chemical barriers to non-natives, changing physical competition dynamics of the system (Belnap et al. 2003; Serpe et al. 2006). Invasive species are often able to take advantage of nutrient pulses and reduced barriers much more effectively and rapidly than native species (D'Antonio and Vitousek 1992; Larsen 1995). Stability and erosion of soils are also compromised upon even slight physical disturbances (Belnap and Gillette 1997, 1998; Belnap 2006).

Post-fire stabilization and rehabilitation seeding or other treatment strategies can further damage BSCs, although the benefits of revegetation efforts may outweigh the ecological cost of this damage (Hilty et al. 2004; Pyke et al. 2013). Hilty et al. (2004) found that range drilling post-fire in the Snake River Plain resulted in more recovery of early colonizing BSC and perennial grasses after 10 years compared to sites that were burned and not drill seeded. Additionally, standard drill seeding is often viewed as the most cost-effective and successful seeding strategy in the Great Basin (Hilty et al. 2004, Whitcomb Chapter 2 and unpublished data). New research is assessing the veracity of that belief, even with regards to soil stabilization (Arkle et al. 2014; Knutson et al. 2014). Minimum-till drills and no-till drills can be used, but have higher costs (both monetary and logistic) associated with them and cannot be used on all sites (e.g., slope and/or rockiness constraints).

While there are some studies that evaluate the effects of these seeding strategies on BSC recovery, the relationship between BSC response/recovery post-seeding strategy in the field has only been investigated in the Great Basin by one study (Aanderud 2014); target vegetation response based on BSC post-wildfire and post-drilling response has not been assessed in the Great Basin. We do also know that cyanobacteria can recover relatively quickly post-disturbance, while recovery of mosses and lichens has been estimated to take 45 to 250 years, respectively (Belnap 1993). Do different types of soil disturbance (e.g., seeding drilling strategies) affect different functional/morphological stages of BSC enough so that we see significant differences in target plant responses (e.g., emergence and survival)? Understanding the relationship between BSC response and target plant response to different seeding strategies may be valuable information both for ecologists in building ecosystem models and for land managers developing rehabilitation proposals.

Monitoring BSCs by Functional Group

Perceived logistical difficulty identifying BSC may be one reason rangeland managers have not monitored biological soil crusts (West 1990). In an effort to create a standardized monitoring protocol, Eldridge and Rosentreter (1999) devised BSC functional groupings based on morphology. Tyler (2006) found these morphological classifications to better represent ecological health than dimensionality indices (height/structure) or percent cover.

However, it is possible these protocols still may be too simplistic. The technical reference "Interpreting Indicators of Rangeland Health" (IIRH), version 4, (Pellant et al. 2005) describes the base measurement of soil crusts as "visible biological crust (e.g., lichen, mosses, algae)"; all other crusts (less visible cyanobacteria and algae) are recommended to be noted as bare soil. Following this protocol, more detailed BSC information can be included per the discretion of managers. Currently, the projects that do assess BSC in the northern Great Basin often simply note: "bare soil," "moss," or "lichen," as evidenced in the Sagebrush Sagebrush Steppe Treatment Evaluation Project (SageSTEP) monitoring protocol. SageSTEP is one of the largest projects ever funded by the Joint Fire Science Program (JFSP).

While a simplified monitoring is understandably desirable, certain important ecological aspects may not be addressed by the data. For example, some cyanobacteria can absorb eight times their weight in water (Belnap and Gardner 1993) and supply structural integrity, even when they are dead but still intact after a disturbance (Belnap 1993). Yet communities composed solely of cyanobacteria would be designated "bare soil" following standard IIRH protocol. Additionally, different BSC morphological groups tend to occupy different microsites in the ecosystem and their presence or loss can result in varying ecological consequences (Eldridge and Rosentreter 1999). For example, *Syntrichia ruralis* forms extensive monospecific mats under shrubs and grass canopies (Rosentreter 1994; Hilty et al. 2003) and can store ~ 14.2 L/m^{-2} of water (Eldridge and Rosentreter 2004). Relative abundance of short-mosses has been shown to increase post fire, while tall mosses and lichens abundances decrease (Kaltenecker 1997; Hilty et al. 2004). Thus, the loss of tall-moss alone can have big impacts on ecosystem hydrology (Hilty et al. 2003). Losing tall-moss may also affect invasive species establishment differently than other species of mosses (Serpe et al. 2006). Using the standard IIRH monitoring system these unique traits of tall-moss can be missed simply by enough other species of mosses being recorded as 'moss'. If these different morphological communities have an appreciable effect on restoration seeding success or invasive species exclusion, a case could be made for expanding the IIRH protocol for all Great Basin landscapes.

The objective of this study was to determine the effects of post-fire BSC development on different seeding strategies. The study presented herein provides initial exploratory information regarding the following question: Does it matter to post-fire restoration success whether different seeding strategies are used on different BSC development stages? As very little previous research exists on this topic, we approached these questions with a pilot study, simply to see if trends exist that may be worthy of further study.

Methods

In 2013, biological soil crusts and underlying soils were collected from an eastern Great Basin cold desert sagebrush shrubland—Rush Valley in Tooele County, Utah (40°05'27.43”N 112°18'18.24”W BYU site; 40°04'38.34"N -112°20'22.06"W collection site, elevation 5552ft, 1692m). A custom soil survey report for the area (2,605.9 acres) was generated using Web Soil Survey (Soil Survey Staff 2014). Mean annual precipitation of the area is 25-30 cm (10-12 in) and mean annual air temperature 7-11ºC (45-52ºF) (Soil Survey Staff 2014). The profile described in the field and properties of the soil samples determined in the laboratory were consistent with ranges given in the soil map unit of Taylorsflat loam, though possibly sandier (sandy loam). Soils of the Taylorsflat series (fine-loamy, mixed, superactive, mesic Xeric Haplocalcids) are formed on fan remnants and lake terraces from mixed alluvium and/or mixed lacustrine deposits. They tend to be well drained loams from 0-1.5 m (0-60 in) and more than 2 m (80 in) to water table or restrictive features.

Vegetation was dominated by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), Sandberg bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and cheatgrass (*Bromus tectorum*). Shadscale saltbush (*Atriplex confertifolia*), bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), western yarrow (*Achilea millefolium* var *occidentalis*), and other forbs and cactus were also present although less abundant (Appendix D, Table 1). Gooseberry globemallow (*Sphaeralcea grossularifolia*) and Needle-and-threadgrass were observed nearby in the summer of 2013 and had been documented locally (SageSTEP unpublished data).

Seeds of most species, including the invasive cool-season annual grass *Bromus tectorum* (cheatgrass), were collected from Cache and Box Elder Counties in 2011-2013 by the USDA Agricultural Research Station (ARS) Forage and Range Research Laboratory (FRRL) in Logan, UT (Appendix D, Table 2). The species in the restoration seed mix were selected for presence and compatibility with the Rush Valley site, availability to us as well as likely availability to managers, and desirability as a restoration species. Restoration species were: bluebunch wheatgrass (*Pseudoroegneria spicata*), bottlebrush squirreltail (*Elymus elymoides*) "rattlesnake," Indian ricegrass (*Achnatherum hymenoides*), needle-and-thread grass (*Hesperostipa comata*), western yarrow (*Achilea millefolium* L. var. *occidentalis*), and gooseberry globemallow (*Sphaeralcea grossulariifolia*). Seeds of all species were stored at room temperature until used.

BSC morphologies were identified based on Eldridge and Rosentreter's (1999) morphological groupings. Five BSC groups were collected with 8cm of underlying soil; each group was collected in 2 separate square plastic containers (18.5 x 18.5 x 10 cm) (see Fig. 4.1 and Appendix D for more detailed field and lab notes including vegetation and biological soil crust species):

- M1: soil with very little BSC development ("bare soil" in most assessments)
- M2: early cyanobacteria likely composed of *Microcoleus vaginatus* but lacking extensive rippling or ridging and pale in color

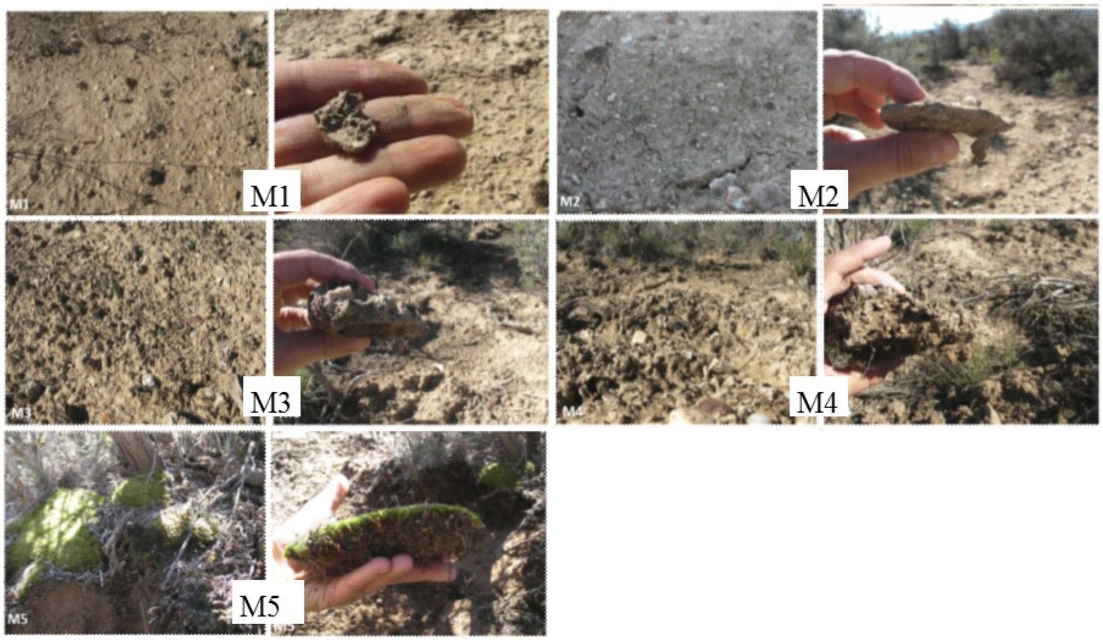


Fig. 4.1. Biological soil crust morphologies and fragments: showing structural integrity in Rush Valley, UT, October 2013. Four interspace developmental morphologies (M1:M4) and one undershrub morphology (tall-moss, M5).

- M3: early/mid-cyanobacteria likely composed of *Microcoleus vaginatus* and that is visually obvious (rippling, ridges, thicker, darker)
- M4: a diverse moss/lichen community (as most lichens grow slowly, a well-developed lichen community is considered late seral, Kaltenecker 1994)
- M5: not successional with M1:M4; tall-moss mats, predominantly *Syntrichia ruralis*.

The first four BSC were collected from interspaces between shrubs. A flat shovel was used to excavate samples down to 10-15 cm and lift them out as intact as possible. Broken apart BSC was pieced back together. All BSC were collected from a 100 m^2 area. M1 and M2 were collected from the west side of the road where BSC development was minimal due to some past disturbance (50 m^2 area). M3, M4, and M5 were collected from the east side of the road where lack of recent disturbance has allowed increased BSC development (50 m^2 area). Truly bare soils were not collected because there was none available at the site. Creating bare soil for a control by scraping the BSC off does not account for nutrient holding dust deposits (Reynolds et al. 2001), possible physical crusting that can happen on bare soils (Belnap 2001), or pioneer bacteria that may come in (Aanderud 2014). Additionally, this pilot study was designed to assess seeding strategies between the different groups, not seeding strategy effectiveness on bare soils. M1 soils were treated as the control when modeling BSC group effect across seeding strategies. Vegetation and BSC species presence were recorded in 1 m^2 at each of the five BSC excavation sites (Appendix D: Table 1). On each side of the road, a ~ 50 cm deep soil profile was described following the United States Department of Agriculture (USDA) Soil Quality Test Kit Guide (2001) Chapter 11 Soil Physical Observations and Estimates. Biological soil crust structure, morphology, and depth were also recorded. Samples from A and B Horizons were analyzed in the Utah State University Pedology Soil Genesis lab following the USDA Soil Quality Assessment Guidelines (2001) and lab protocols for bulk density, EC, and pH.

Seeds were prepared at the Utah State University (USU) Research Greenhouse Complex (Logan, UT) following the methods of Serpe et al. (2006) and personal communication with USDA-ARS FRRL. Indian ricegrass and gooseberry globemallow seeds were both manually scarified using 40 grit sandpaper underneath and 100 grit sandpaper on top. The seed of these species and those of bottlebrush squirreltail (not scarified) were then soaked in deionized water for 24 h. Seeds of all species except needle-and-threadgrass and cheatgrass were cold-moist stratified. Seeds were placed in germination boxes on top of germination blotter paper saturated in deionized water. They were cold-moist stratified for three weeks in the USU Research Greenhouse Complex refrigerator (24h dark and 4ºC).

BSCs were misted daily on an east-facing greenhouse bench in square plastic containers with four drainage holes in the bottom. Black plastic greenhouse trays (25 cm x 50 cm x 6.4 cm) each held two containers and 3cm of water to allow self-watering of soils via the drainage holes throughout the day (three trays and six containers per BSC morphology, details below). Trays were kept in the greenhouse for 15 days (25 degrees C, 16h photoperiod) to allow for the acclimation of BSCs and the germination of the remnant seed bank (Serpe et al. 2006). BSCs were then singed with a heat lamp (1000 watt) for 12 h to simulate a light burn—this was an unintended step and did not follow any previous methods; as such, comparison to actual fire events should be viewed cautiously. We continued to proceed with the study as the extremely preliminary nature of this research would not be drastically altered by this event. Nonetheless, comparisons can be made to other laboratory experiments simulating soil responses to fire. Previous experiments have often used oven heating—this, similar to our study, does not account for the direct effects of flames (Stoof et al. 2010); however, ovens heat soils uniformly while grow lamps heat from above, slightly more similar to in-situ field conditions. Indeed, a new technique recently used by Wieting (2016) used a 1500 Watt heat gun to account for top heating rather than oven heating. As BSC are generally resilient to drought and high temperature conditions, and as the BSC in the present study did not "green up" after watering (and had previously following desiccation in the same greenhouse) it was determined this heating event could be used to simulate, at a minimum, a slightly more intense heat that would be generated from a fire compared to the sun.

After cold-moist stratification of the seeds ended, two containers of each BSC morphological group were seeded by “range drill,” “minimum till drill,” or “broadcast.” Range drilling was accomplished by raking the soil surface in rows using a small auger (1.3 cm diameter). The soil surface of the minimum till treatment was not disturbed. The small auger was used to poke holes through the soil surface to the appropriate depth per species (½ inch for native grasses, ¼ inch for native forbs, Appendix D: General Plant Characteristics) for both the range drill and minimum till seeding strategies. Broadcast seeds were simply placed on top of the soil.

Due to the exploratory nature of this greenhouse study and limited greenhouse space, we did not try to simulate spatial heterogeneity in the soil where remnant surviving cheatgrass seed and wind/animal dispersed seed might cache. Rather, using the same methods as the other species, we placed the cheatgrass seed on the surface in their own randomly allocated squares (see below).

To plant seeds, each container was divided into a seven row by seven column grid; in each row, each species’ seed was randomly allocated to one “square” (spaced using a 2.54 cm.^{2} grid) to minimize interspecific plant interactions on germination and emergence. This resulted in 49 squares seeded per container. Twenty seeds were planted in each square. If needed, plants were thinned to ten upon emergence to lessen intraspecific interactions. Each morphological group*seeding treatment had two containers. For example, in the tall moss range drilled container, 20 bluebunch wheatgrass seeds were placed in one hole per row, in seven rows (140 seeds) per container, in two containers, for a total of 14 holes (280 seeds). Morphology*seeding treatment containers were not randomized as placing different BSC groups and/or seeding treatment in the same tray could result in uneven water utilization rates. This pilot study occupied a small enough space in the greenhouse that we were not overly concerned with tray randomization (Fig. 4.2). Emergence (true leaves or cotyledons emerge) and establishment, or survival, of individual plants (excluding thinned plants) were monitored every other day. Survival was defined as those plants that survived through the entire experiment, excluding the last two weeks (when many of the grasses started to turn brown). The experiment ended before these browned grasses started to decompose.

Seed viability rates were tested in the USU Research Greenhouse Complex lab using four replicates of 100 seeds. Seeds were placed on germination paper saturated with

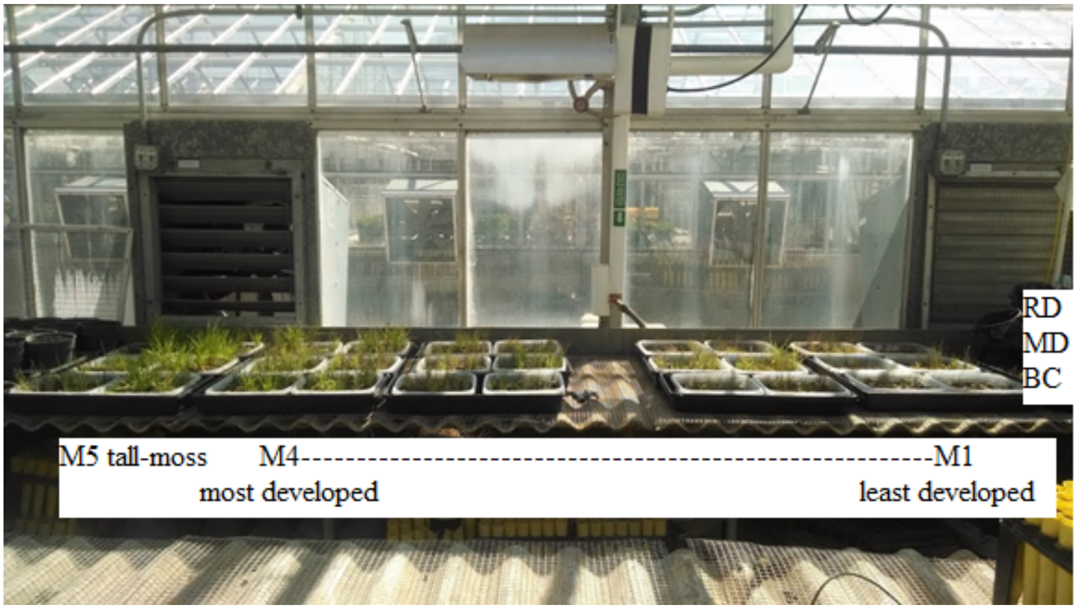


Fig. 4.2 East facing bench: in the USU Research Greenhouse Complex, August 2014 (Logan, UT). 'Range-drilled' (RD) trays (two containers in one tray for each BSC group) are closest/westernmost, 'minimum-till' (MD) trays are in the middle, and furthest/eastern trays are broadcast seeded (BC).

deionized water in Petri dishes for three weeks and checked daily for germination (radicle 2-4 mm long) for 2 weeks.

Data Analysis

Data were analyzed with linear mixed effects models using the open-source software program R (2015) lme4 package (Bates et al. 2015) to test both interaction between BSC (M1:M5) and seeding treatment (broadcast, minimum-till, standard drill) as well as main effects of each of these model factors on each species' emergence and survival. Overdispersion (much larger combined residuals than residual degrees of freedom) was assessed using code from Pilowsky (2014). Least squares means (using package lsmeans, Lenth 2016) and simple means t-tests were computed for each BSC*seeding treatment combination (e.g., M1 broadcast*M1 minimum-till, M1 broadcast*M1 range drill, M1 minimum-till *M1 range drill). Least square means are calculated from the treatment structure of a factor on the standard mean; this was especially useful when data included missing or zero values (e.g., none emerged) and/or covariates are present (e.g., BSC and seeding treatment have significant interaction). When covariates were present, means were adjusted for the average value of each covariate. The predictor variables were BSC group (5 groups) and seeding treatment (3 types). The response variables were emergence and survival.

Results

Seedling emergence on BSC was often similar to seed viability tests; however, emergence of bottlebrush squirreltail and gooseberry globemallow seeds was much higher in the lab than on BSC in the greenhouse (Table 4.1 and Appendix D: Table 2 and Appendix E). Survival in the greenhouse was also lowest for those two species and Indian ricegrass. Western yarrow experienced some heavy mortalities following emergence in the greenhouse (discussed below).

Interaction between BSC group and seeding treatment on emergence was common, significantly affecting 5 of 7 species, including cheatgrass (Table 4.2 and Appendix E). Interaction between BSC group and seeding treatment on survival was much less common, with only 2 of the 7 species exhibiting significant interaction (Needle-and threadgrass and gooseberry globemallow). The main effect BSC group was a significant predictor of survival for two native grasses (and near significant for another), one native forb, and cheatgrass. The main effect seeding treatment was only a significant predictor of survival for one native grass.

Overall Seeding Treatment Results

Minimum till drilling was associated with improved emergence and survival when compared to standard range drilling for most species (with the exception of needle-and-threadgrass and Indian ricegrass, Figs. 4.3–4.9 and Table 4.2, Appendix E) and broadcast seeding (5 out of 6 native species, exception western yarrow). Needle-and-threadgrass and Indian ricegrass emergence and survival increased when seeded with either drilling strategy compared to broadcasting seed (Figs. 4.5–4.6). Emergence of bluebunch wheatgrass was only significantly improved on 2 out of 5 groups when range drilled compared to broadcast. Bottlebrush squirreltail emergence was never significantly

Table 4.1

Mean emergence (in the lab, out of 20), emergence (in the greenhouse, out of 20), and survival (out of n emerged, thinned to 10 maximum) averages. Mean emergence and survival ranges were determined from all BSC groups and seeding treatments.

	Emergence (lab)	Emergence (greenhouse)	Survival
Bluebunch wheatgrass	84%	44-87%	62-99%
Bottlebrush squirreltail	32%	2-9%	4-14%
Needle-and-threadgrass	37%	4-56%	7-99%
Indian ricegrass	20%	0-17%	1-28%
Western yarrow	91%	60-100%	0-84%
Gooseberry globemallow	64%	3-15%	4-31%
Cheatgrass	71%	50-96%	68-99%

Table 4.2

Grass and forb response interactions and fixed factors. Ovdisp = corrected for overdispersion, sq.rt = square root transformed. *significant < 0.1, ** < 0.05, *** < 0.005.

Grasses:	Bluebunch wheatgrass		Bottlebrush squirreltail		Needle-and-threadgrass		Indian ricegrass		Cheatgrass	
	Emerged	Survived	Emerged	Survived	Emerged	Survived	Emerged	Survived	Emerged	Survived
(Model fit)	Ovdisp			sq.rt	Ovdisp			sq.rt		
Interaction	*				**	***	**		**	
BSC group	***		**	**	***	***	**	**	**	*
Treatment	***				***	***	***	***	***	

Forbs	Western yarrow		Gooseberry globemallow	
	Emerged	Survived	Emerged	Survived
(Model fit)				
Interaction			**	**
BSC group		***		
Treatment			*	

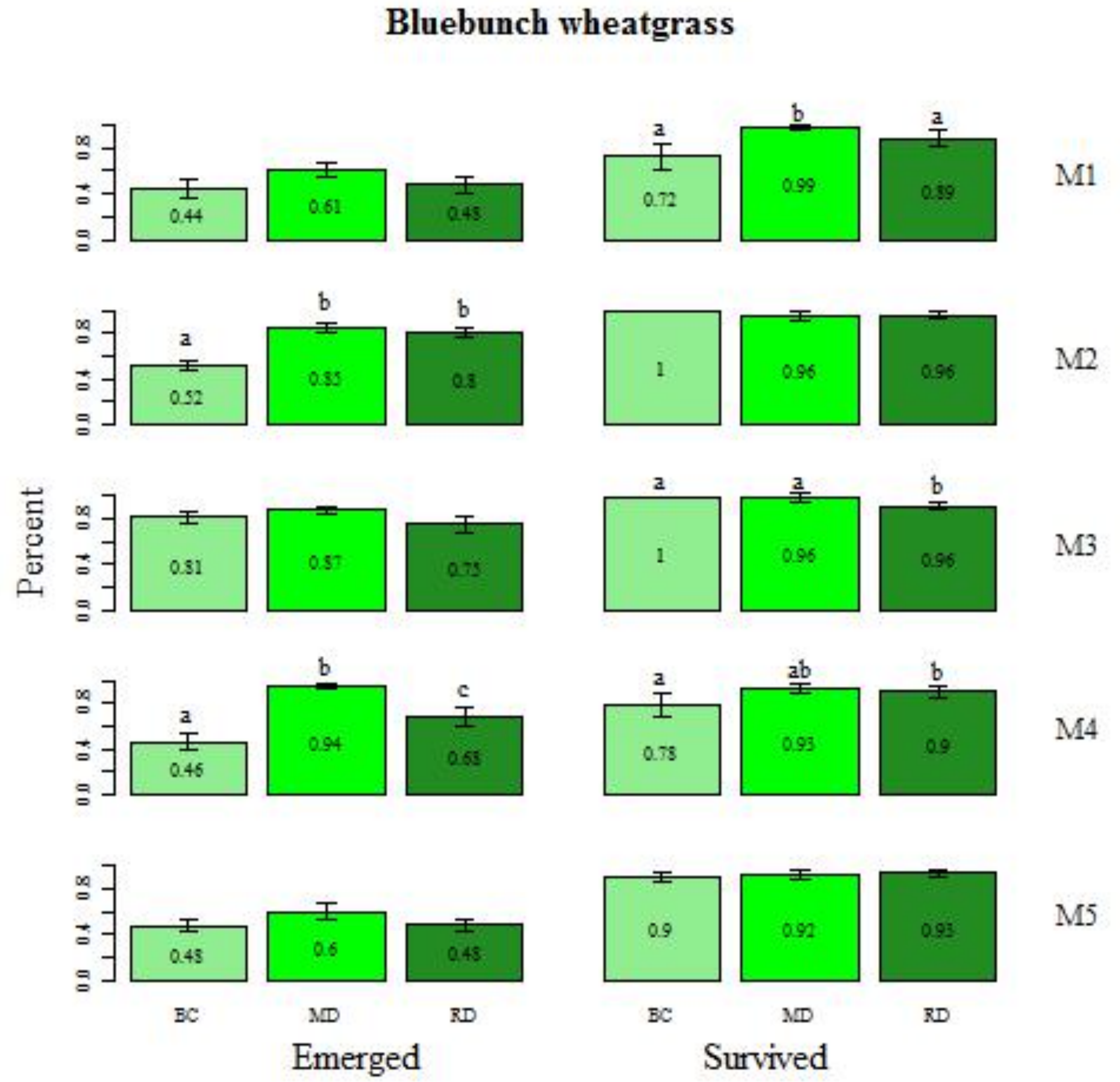


Fig. 4.3. Bluebunch wheatgrass response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

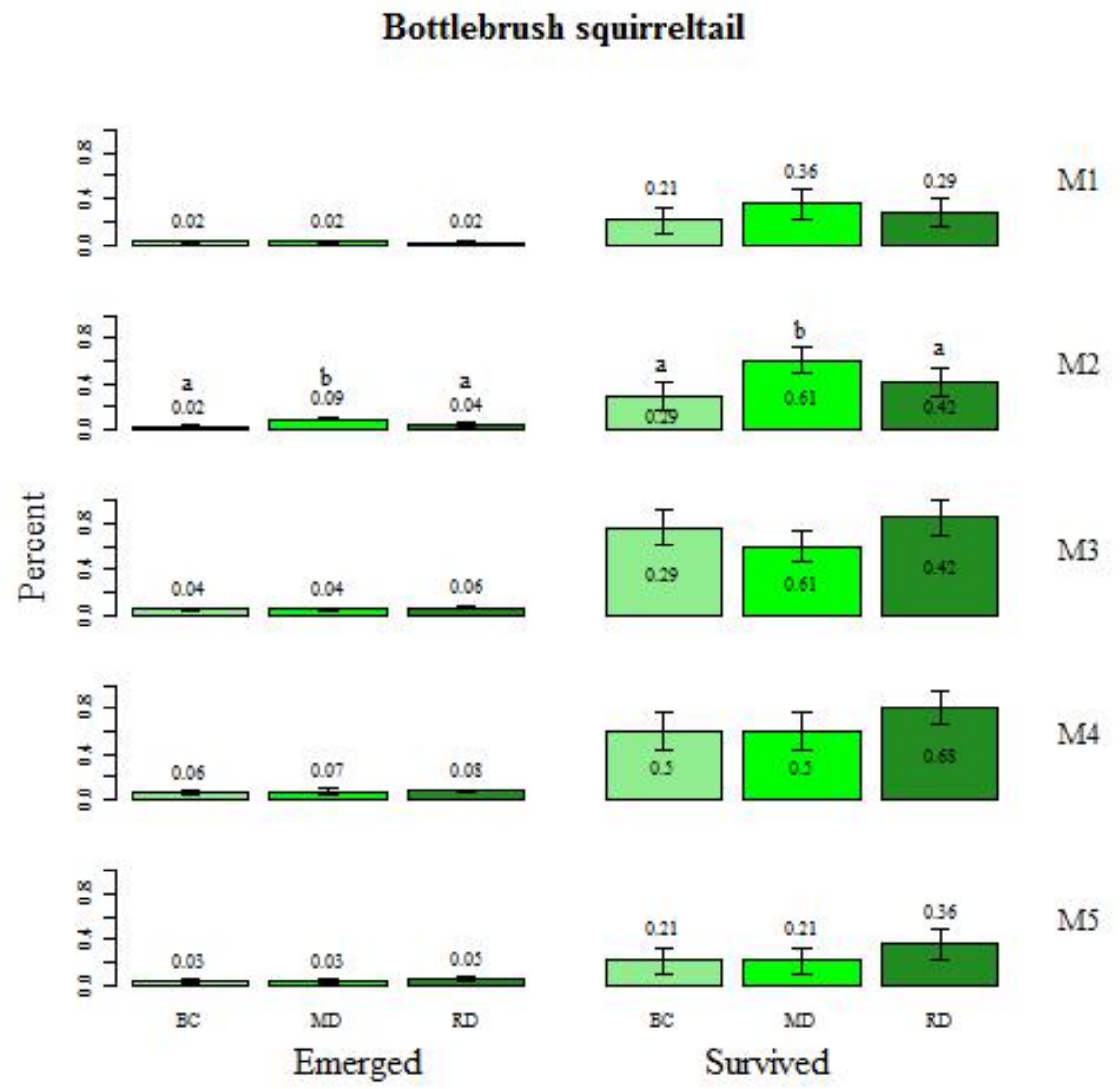


Fig. 4.4. Bottlebrush squirreltail response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

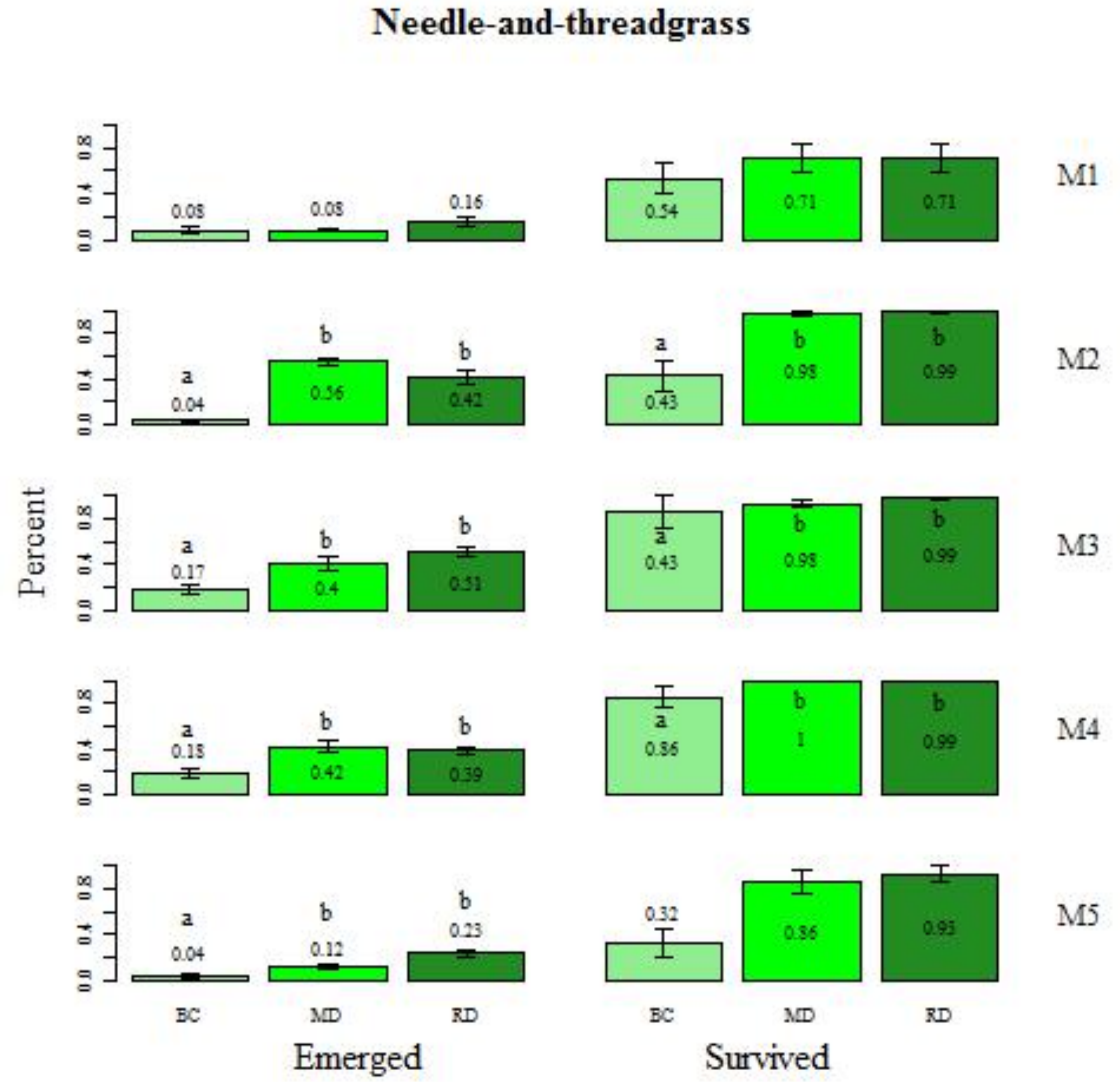


Fig. 4.5. Needle-and-threadgrass response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

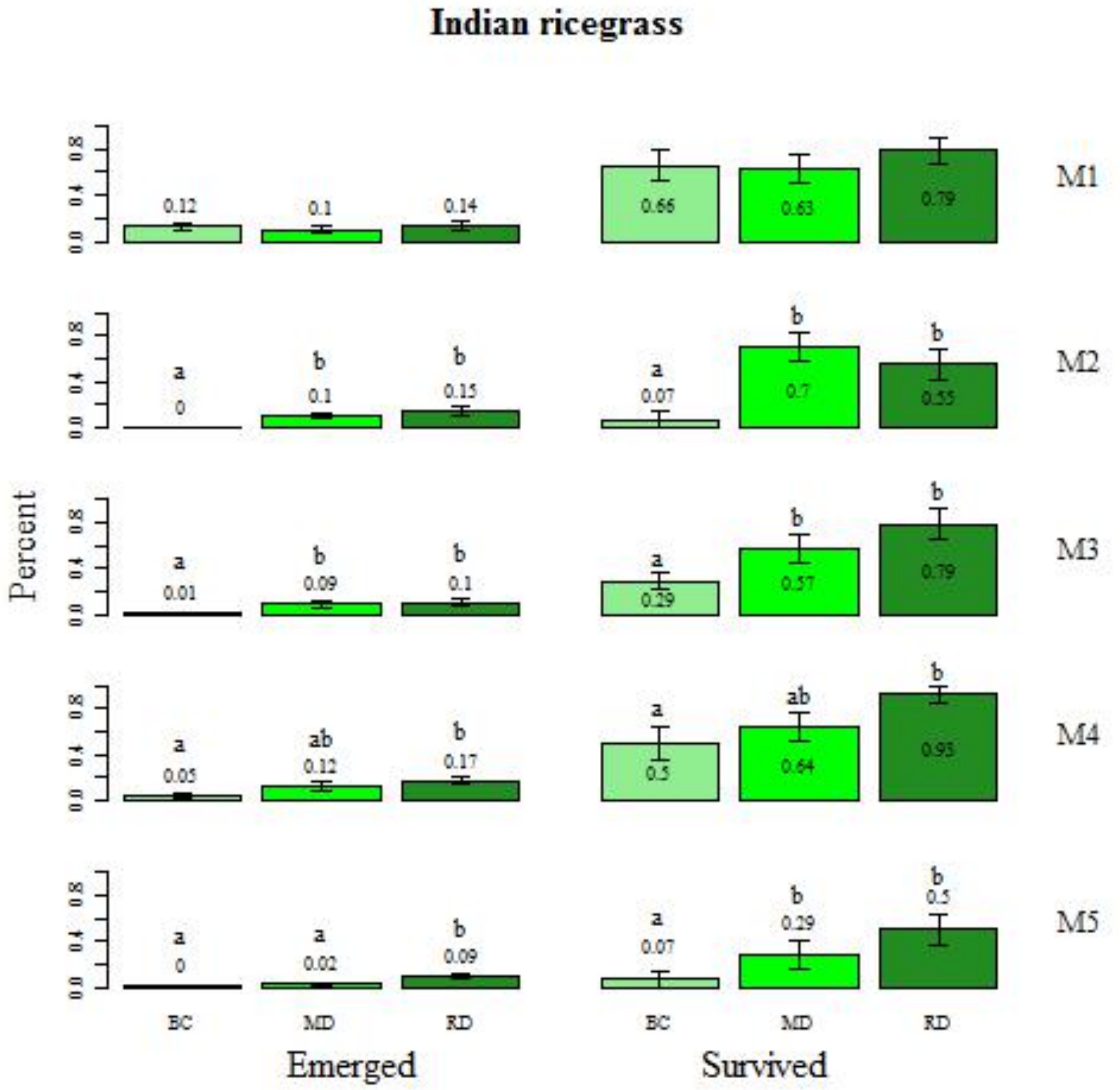


Fig. 4.6. Indian ricegrass response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

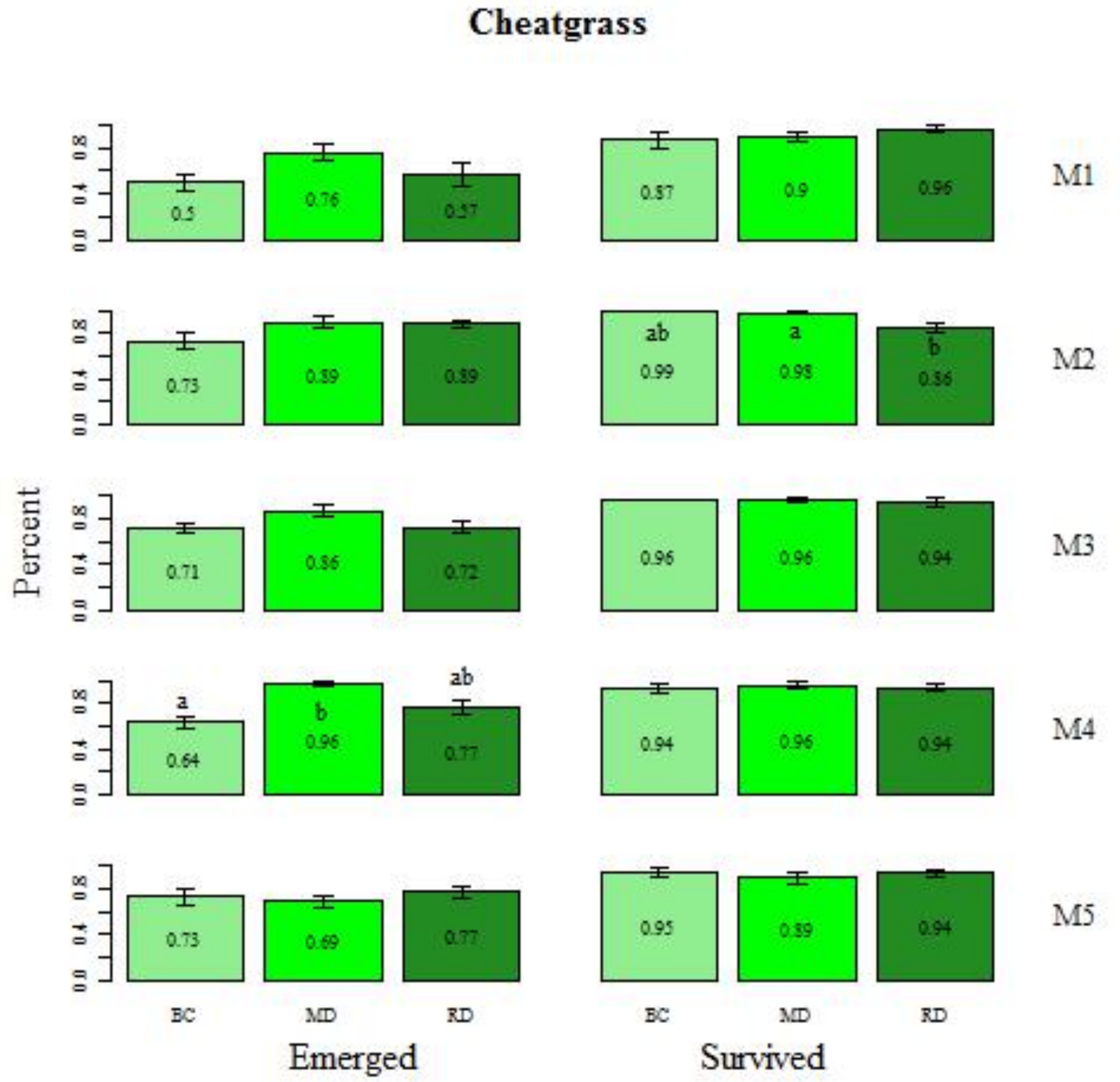


Fig. 4.7. Cheatgrass response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

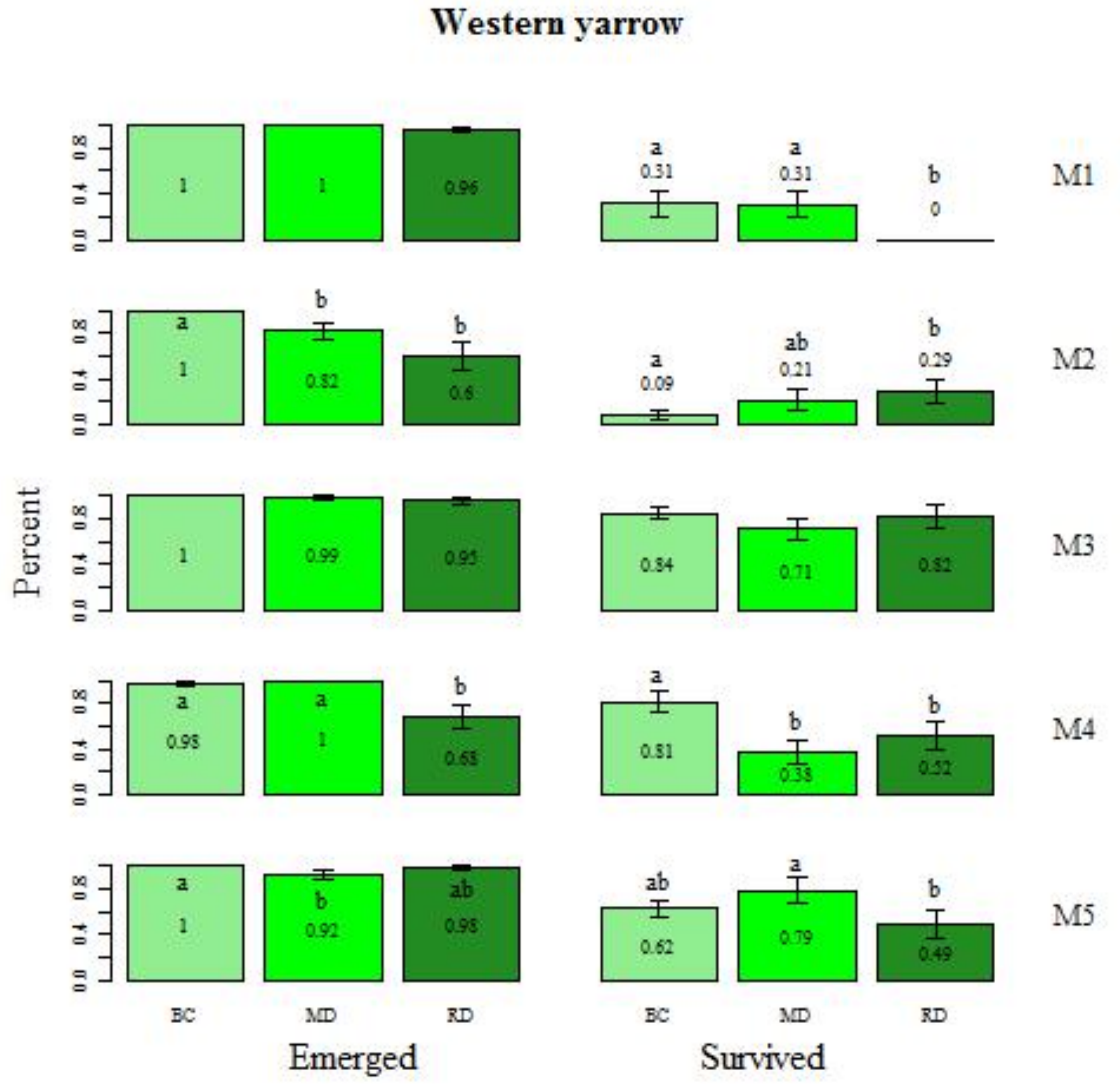


Fig. 4.8. Western yarrow response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

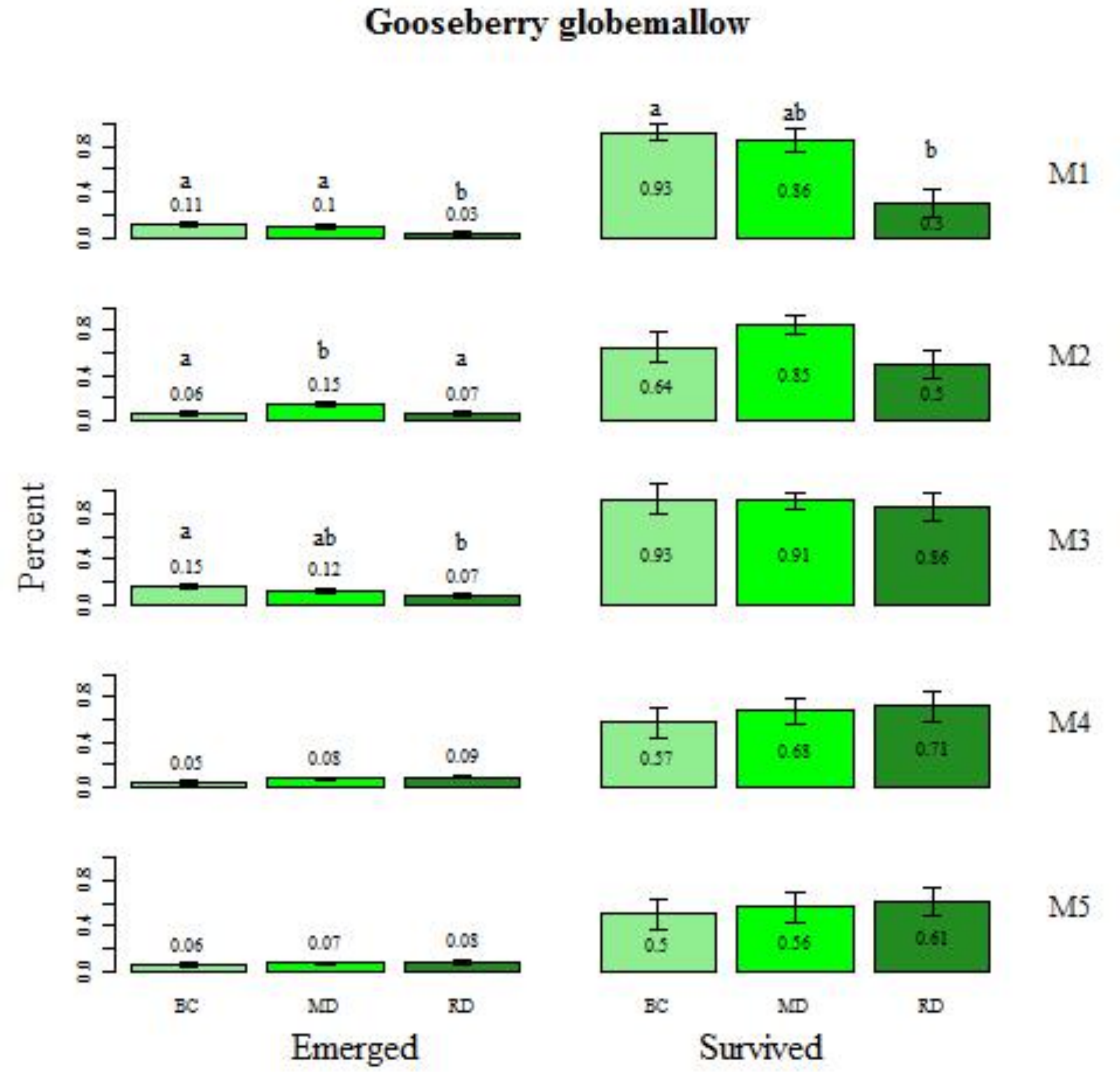


Fig. 4.9. Gooseberry globemallow response to different seeding strategies: mean and standard error bars for seeding treatment by BSC group.

improved by range drilling compared to broadcasting seed; likewise, survival of both bluebunch wheatgrass or bottlebrush squirreltail was never significant between these two seeding strategies (Figs. 4.3–4.4).

Forbs emergence and survival often increased when broadcast seeded compared to range drilled (Figs. 4.8–4.9). In greenhouse conditions, intact BSC did not significantly inhibit cheatgrass emergence; once emerged, cheatgrass survived equally well on both intact and disturbed BSCs (Fig. 4.7).

Bluebunch Wheatgrass

Over all BSC groups, emergence for bluebunch wheatgrass was highest when seed was minimum-till drilled and on four BSC groups, lowest when broadcast (Fig. 4.3, Table 4.2, and Appendix E: Tables 3-6). When bluebunch wheatgrass was seeded with the range drill treatment, emergence and survival averages tended to be higher than when the seed was broadcast; however, survival averages were never significant between these seeding treatments were never significant. Emergence and survival were significantly higher for the range drill treatment, compared to broadcast, on M1, the least developed BSC. Range drilling was not significantly different than broadcast seeding on M1.

Bottlebrush Squirreltail

Both drilling treatments supported similar emergence and survival of bottlebrush squirreltail seeds, while broadcast seeding supported the least (Fig. 4.4, Table 4.2, and Appendix E: Tables 7-10). However, broadcast and range drilling seed establishment averages were never significantly different from each other, and minimum-till drilling only increased emergence and survival significantly on one BSC group compared to broadcasting seed (Table 4.2, Fig. 4.4, and Appendix E: Tables 7-10). There were no differences in emergence or survival of bottlebrush squirreltail with any seeding treatment on M1.

Needle-and-Threadgrass

Needle-and-threadgrass emergence and survival were improved three-fold by both drilling treatments (Fig. 4.5, Table 4.2 and Appendix E: Tables 11-14). The minimum-till and range drilling treatments were never significantly different from each other. While this species typically exhibited increased response averages from drill seeding, on M1, the least developed BSC, there were no significant differences in seeding treatments on either emergence or survival.

Indian Ricegrass

Both emergence and survival of Indian ricegrass were improved 2-3 fold with both minimum-till and range drilling treatments (Fig. 4.6, Table 4.2, and Appendix E: Tables 15-18). Survival for range drilled Indian ricegrass was higher than for minimum-till drilled, however differences were never significant. There were no significant differences in emergence or survival among any seeding strategies on M1, the least developed BSC.

Western Yarrow

Emergence of western yarrow was very high in all BSC groups and seeding strategies; nonetheless, Table 4.2 (and Appendix E: Tables 23-26) demonstrates broadcasting and minimum-till drilling treatments both tended to increase both western yarrow emergence and survival compared to range drilling. Many broadcast western yarrow died in the BSC group M2; indeed, M2 was the only BSC group with a lower survival average when broadcast compared to range drilled. On the least developed BSC group, M1, broadcasting seed resulted in significantly better survival averages compared to either drilling treatment.

Gooseberry Globemallow

Minimum-till drilling gooseberry globemallow tended to enhance emergence and survival compared to other seeding strategies (Table 4.2, Fig. 4.9, and Appendix E: Tables 27:30). Similar to western yarrow, broadcast gooseberry globemallow seeds in BSC group M2 experienced heavy losses. However, broadcasting in BSC group M1, the least developed BSC, significantly increased emergence and survival compared to range drilling (though not compared to minimum till) in the greenhouse. Seeding treatment only resulted in one statistically significant difference for gooseberry globemallow survival (Table 4.2); higher averages in emergence and survival suggested minimum-till drilling may be a more effective strategy when feasible, while broadcasting may result in slightly improved globemallow emergence and establishment when compared to range drilling.

Cheatgrass

Clearly, cheatgrass would never be planted in a restoration project, however it has proven difficult to eradicate even in post-wildfire restoration projects when much of the seed is killed from the fire (Pechanec and Hull 1945; Stark et al. 1946; Stewart and Hull 1949; Pellant 1990). In the greenhouse, cheatgrass emerged and established well on both intact and disturbed soils (no significant differences, Fig. 4.7). Mean cheatgrass emergence was slightly higher on disturbed soils in each of the 5 BSC groups (Fig. 4.7 and Appendix E: Tables 19:22), although this is unlikely to be biologically meaningful given the high fecundity rates for this species. Once emerged, cheatgrass plants on intact soils experienced slightly greater survival averages in 4 out 5 BSC groups (M5 tall moss being the exception).

BSC Group Effects

Interaction between BSC group and seeding strategy was a significant predictor of emergence (Table 4.2) for all species except bottlebrush squirreltail and western yarrow. BSC group alone was significant predictor of bottlebrush emergence. For survival, BSC group was less likely to significantly interact with seeding treatment, only being significant for needle-and-threadgrass and gooseberry globemallow. When interactions were not significant on survival (5 species), BSC group was a significant predictor of survival for 4 species. This includes Cheatgrass. Tall-moss, M5, tended to support lower emergence rates, often comparable to M1, the least developed BSC (Figs. 4.3-4.9 and Table 4.3); however, plants that survived on M5 appeared to be more vigorous (Figs. 4.2 and 4.10).

Minimum-tilled treatments also appeared to support more vigorous plants, while plants in broadcast and range drilled containers often appeared similar. The minimum-till drilling treatment often resulted in reduced BSC group effect (e.g., little to no emergence difference in M2-M4) while range drilling BSC (and sometimes broadcasting) tended to accentuate BSC group effects. In M1, the least developed BSC, the range drilling treatment did not significantly increase emergence or survival for any species compared to other treatments (Table 4.3, Appendix E).

Table 4.3
Emergence and survival BSC group effect (TNA), M5 ≈ M1 (S=Similar, D=Different). P-value < 0.1 = *; effect direction (<,>).

	Broadcast			Minimum-till			Range drill		
Plant	Effect	Trend	M5≈ M1	Effect	Trend	M5≈ M1	Effect	Trend	M5≈ M1
Bluebunch wheatgrass	N	NA	S	N	NA	S	Y	↓	S
Bottlebush squirreltail	Y	↑	S	N	NA	S	Y	↑	S
Needle-and-threadgrass	Y	↑	S	N	NA	S	N	NA	S
Indian ricegrass	Y	↑	D*<	N	NA	D<	N	NA	D<
Western yarrow	N+Y	NA+ ↑	D*>	N+Y	NA+ ↑	D*>	N+Y	NA+ ↑	D*>
Gooseberry globemallow	N	NA	D<	Y	↓	D<	N	NA	D*>
Cheatgrass	Y	↓	D>	-	-	-	N	NA	D*>

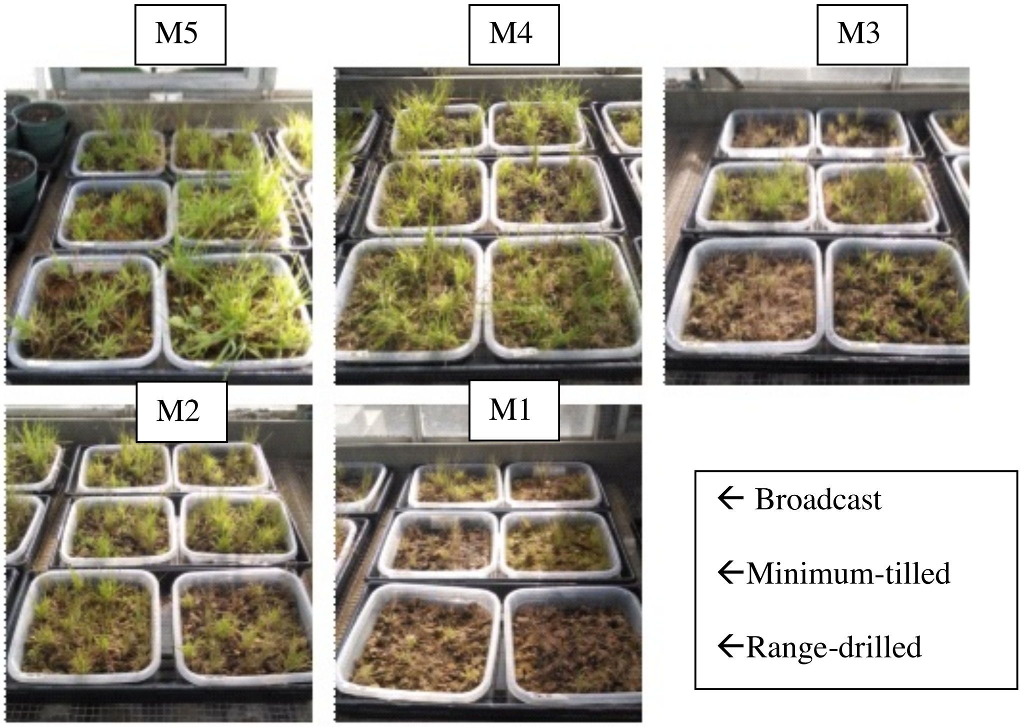


Fig. 4.10. East facing bench close up: in the USU Research Greenhouse Complex, August 2014 (Logan, UT).

Seeds of both forbs had higher emergence and survival averages on M1 when broadcast compared to range drilling (Table 4.2, Figs. 4.8-4.9, Appendix E: Tables 23-30). Cheatgrass (Fig. 4.7) exhibited slightly lower, though not significant, emergence on intact M1 (aka broadcast) compared to disturbed soils (aka range drilled), and survived better, though not significant, on M1 intact BSCs than disturbed BSCs. Of note, seeding into more developed BSC using the range drilling treatment resulted in slightly decreased bluebunch wheatgrass emergence and survival (Fig. 4.3 and Table 4.3). Where BSC was more developed western yarrow survival tended to be greater regardless of seeding treatment (Fig. 4.8 and Table 4.3). Tall moss, M5, and the least developed BSC, M1, were often similar in their influence upon establishment for native grasses, with p-values very close, and sometimes equal, to 1.0 (Appendix E: Tables 1-18). Indian ricegrass was the exception to the grasses, exhibiting lower emergence and survival averages on M5 compared to M1 (Fig. 4.6 and Table 4.3). Both forbs and cheatgrass exhibited differences in average emergence and survival on M1 and M5. Western yarrow seedlings in tall moss (M5) had increased survival averages compared to M1. Emergence and survival averages were lower for gooseberry globemallow under the broadcast and minimum-till treatments; conversely, emergence and survival averages increased on M5 when range drilled. Cheatgrass emergence and survival were greater on tall moss compared to the least developed BSC, M1 (significantly on disturbed BSC).

Discussion

This pilot greenhouse study was designed to assess plant establishment both on BSC likely classified as “bare soil” (yet retaining cyanobacteria) as well as more developed BSC after a fire.

BSC Group and Seed Drilling

The preliminary results from this study indicate interaction between BSC group and seeding treatment may exist and may result in different outcomes for common restoration species. When interaction was not present, BSC group was often a significant predictor of plant establishment. Four possible hypotheses for further testing emerged:

1. Range drilling may eliminate the benefits of seeding into M1 vs. truly bare soil,
2. Minimum-till drilling may not exhibit as pronounced a BSC group effect as range drilling or broadcast seeding,
3. Tall moss (M5) may experience the least seeded plant emergence, but once established this BSC group may support increased survival and possibly vigour, contributing to micro fertile islands effects,
4. BSC group and drilling interaction interpretations vary per species and management objectives
5. More developed BSC may not inhibit cheatgrass emergence as much as expected; while this was likely due to ideal greenhouse conditions, relationship to burning cannot be ruled out with this pilot study.

Conclusion

Point 1.

The range drilling treatment compared to broadcasting seed on the most poorly developed BSCs (M1) did not seem to increase emergence or establishment of bluebunch wheatgrass, bottlebrush squirreltail, or either forbs, even with the probable "first year" nutrient pulse. These are soils that typically would be classified as "bare soil" using the IIRH criteria used by federal land management agencies, and yet they exhibited supporting roles for some plants. Immediate stabilization of bare soils is often considered necessary, although recently some have begun to question whether range drilling really does stabilize soils in an effective timeline (Miller et al. 2012; Germino 2013; Pyke et al. 2013). Emergency stabilization may also be hindered by predictably low precipitation; a recent study by Pilliod (2015) found that precipitation in the year immediately following big wildfire years is often low and likely inhibiting restoration efforts. Consequently, while first-year plant material could theoretically stabilize the soils initially if water is available, the diminishing returns from burned and mixed BSC and likelihood of decreased water availability following a big fire year, seem to suggest it would be useful to evaluate whether soils at post-fire rehabilitation sites are truly "bare" when choosing whether to use a rangeland drill at degraded sites immediately following a big fire year.

Many of the studies evaluating drill effectiveness in sagebrush restoration are conducted on severely degraded sites—little if any biological soil crust remains on these sites. Nonetheless, our results seem to agree with the general consensus that minimum-till drilling when possible may represent the best reseeding strategy. Indeed, Shaw et al. 2011 found that even when range drilling supports more plants in the first year on severely degraded sites, this effect appears to be gone by the second year. Choosing to minimum-till drill instead of range drill could also retain biological soil crust components (structure and any remaining viable propagules) beyond the first year. First-year nutrient pulse effects would likely diminish over time with range drilling, as evidenced in Shaw et al. (2011).

Point 2.

Interestingly, minimum-till drilling did not exhibit as pronounced a BSC group effect in M2:M4 (second least developed BSC—most developed BSC), even when burned. This suggests managers may be able to expect more consistent results from minimum till drilling across the landscape in all but the least developed BSCs and tall moss patches.

Point 3.

Singed tall-moss (M5) often prevented native plants from emerging, but once established, M5 may support increased survival. *Syntrichia ruralis* mats are found predominantly in patches under sagebrush canopies. If sagebrush remain, these areas are more likely to be protected from wind and retain water and nutrients (through litterfall) more effectively due to sagebrush structural protection and tall-moss characteristics. In the field, these mosses were very easily destroyed even when wet—a moderate footstep completely destroyed the structural integrity of dry tall-moss mats (personal observation 2013). If tall moss and the shrubs that support them, remain after a fire, hand planting seed in wet mats would likely be the most effective strategy to ensure soil contact and avoid tall-moss destruction. Indeed, due to the increased water holding capacity of tall-moss mats (Eldridge and Rosentreter 2004), tall-moss/shrubs might be considered prime candidates for establishing shrub-based islands of fertility.

Point 4.

Western yarrow is the only species in this mix that is typically broadcast seeded. In our study, it still established well under the minimum-till treatment. If the extra step of broadcast seeding without a modified drill is prohibitively expensive, despite the lightness of this species' seed it is possible that minimum-till drilling at an appropriate shallow depth could be successful (or covering with some other material). Broadcasted seed tended to be less buffered from events for both forbs, even in the greenhouse.

Our pilot study results suggest broadcast seeding (and covering) could be more suited to some management objectives than range drilling. For example, if forbs are an important management objective, certain grasses can be chosen to complement them that are more likely to establish when broadcast on intact BSC than other grasses (e.g., bluebunch wheatgrass rather than Indian ricegrass). Conversely, on intact, less developed BSC, when needing to broadcast seeding Indian ricegrass may increase the probability of meeting grass establishment goals. Indian ricegrass prefers sandy soils and our soil samples indicated these sites were more similar to a sandy loam than a loam (Appendix D: General Plant Characteristics). More developed BSC are thicker than less developed BSC (see Fig. 4.1), which also results in a thicker barrier between seeds and the underlying sandy soil; mixing the soil by "range drilling" assisted Indian ricegrass contact with its preferred soil texture. However, on M1, broadcast Indian ricegrass seeds may have emerged and survived similarly to range drilling due to the less developed, sandier, and thinner BSC barrier (Fig. 4.1). These differences highlight the potential importance of accounting for BSC variation across the landscape.

This is not to suggest these forbs can never be range drilled or broadcast with modified drills, but our results do suggest managers may be able to expect lower forb success when forbs (even heavier seeded ones) are range drilled into biological soil crust. Drilling often seems to be more effective for species with larger seeds, while broadcasting is suggested for smaller seeds (e.g., western yarrow, penstemons, and sagebrush [Ott and Shaw 2013]). In their study, a different species of globemallow (Munro's) was drilled, following USDA Plants database recommendations; gooseberry globemallow documentation suggests this species can be drilled or broadcast. Globemallow seeds are small; their heavier weight likely motivates range drilling recommendations. However, I could find no studies or documentation supporting drilling either Munro's or gooseberry globemallow. In the pilot study presented here, the broadcasting treatment outperformed the range drilling treatment for gooseberry globemallow. However, as broadcasting seeding rates are often double those for range drilling, the cost-benefit ratio of range drilling less seed for less outcome could still be preferable in some scenarios.

Our pilot study results also suggest range drilling may be the preferred option on most BSC groups if establishment of needle-and-threadgrass or Indian ricegrass is a priority. Or, as the other two grasses were not necessarily harmed by range drilling, range drilling all grasses and broadcasting forbs may be appropriate with a modified drill. However, there are several caveats that must be considered with a range drilling approach: first year versus subsequent year effects, soil stability, BSC group effects, and BSC recovery potential (the latter 2 discussed in later sections).

In the first year following range drilling, plant response is often increased due to nutrient pulses from the tillage of the soil. We also found range drilling two of the heavier seeds (needle-and-threadgrass and Indian ricegrass) was beneficial; though not tested in this study, these two grasses require sandier soils, and destroying the BSC with the range drilling treatment likely reduced barriers to the sandier soils underneath. However, at least on severely degraded sites, evidence suggests first year effects may not have a lasting effect on overall site resilience; Cox et al. (2009), Ott and Shaw (2013) and Jenson (unpublished 2011) all suggest diminishing returns in subsequent years occur both for native establishment and cheatgrass exclusion on range drilled sites.

Ott and Shaw (2013) did not find a difference in post-fire dust flux rates from drilling type on highly degraded sites with little, if any, BSC. Indeed, range drilling may not provide even short-term soil stability goals (Pyke et al. 2013). Our results from minimally developed BSC (M1 and M2) seem to suggest that range drilling these nascent BSC may be detrimental for establishment of some restoration plants. It is likely the sites studied by Ott and Shaw were so degraded already that no BSC was present to stabilize it regardless of seeding strategy. On our least developed BSC there were some cyanobacteria providing stability, which is visually obvious in Figure 4.1. A follow-up field study might evaluate if this is enough development to retain structure and diminish dust flux rates following minimum-till drilling (and compared to range drilling).

Point 5.

Singed BSC group did not inhibit cheatgrass emergence as much as expected, likely due to ideal conditions in the greenhouse and this species' ability to readily take advantage of resources (although burning effect cannot be ruled out in this pilot study). The slight differences in cheatgrass emergence and survival are likely biologically negligible when considering this species' high seed production per plant. More research on burned remnant BSC and cheatgrass exclusion is needed.

Caveats and Future Research Directions

Keeping soils at field capacity throughout the growing season is clearly not ecologically realistic in the semi-arid Great Basin. This is often the major caveat of greenhouse studies, as ideal conditions (soil, light, wind, predation) are maintained. Ideal conditions, such as field capacity soils, may benefit one species over another while more realistic conditions in the field may differentially benefit the other species. However, ideal conditions can also initiate the discovery of important differences on a limited budget—if these effects matter in greenhouse conditions, the effect may be worth exploring further in field conditions.

Seed predation, desiccation due to exposure, losses to wind, wind soil erosion, and folivory are also unaccounted for in the greenhouse. While it could be easy to assume the first four effects would be reduced by range drilling in the field, the ecological reality is likely much more nuanced. In the field, native seeds may be more camouflaged on intact BSCs, protecting them from visual seed predators such as birds (Hernandez and Sandquist 2011). Native seeds often have specialized mechanisms that accelerate seed burial in intact BSCs (Stamp 1984; Larsen 1995; Howell 1998; Belnap et al. 2003; Dienes et al. 2007); these processes are further facilitated by improved water retention of intact BSCs, both on the surface (Stohlgren et al. 2001; Maestre et al. 2002; Morgan 2006) and below ground (Brotherson and Rushforth 1983; Campbell et al. 1989; Gold and Bliss 1995; Fierer and Gabet 2002). Furthermore, in the field, wind and soil erosion in the first 3 years post fire on sensitive sites was actually exacerbated by drill seeding efforts (Miller et al. 2012), suggesting range drilled seeds in windy field conditions may not have much more protection than in greenhouse conditions. However, in the greenhouse, the nutrient laden dust is not being blown out of the system, as might occur in the field. Finally, folivory is also unaccounted for in the greenhouse. If differences in folivory by small mammals based on seeding strategy do exist, they would likely be predicted by overall site attractiveness and shrub cover (Sharp and McMillan 2014). Indeed, Freeman et al. (2014) and Ostoja and Schupp (2009) found increasing cheatgrass abundance reduced small mammal abundance and diversity, and research by Sharp and McMillan (2014) seems to suggest small mammals forage differently after a fire, consuming less seed in burned sites. Site attractiveness to small mammals is likely to be highly dependent on year and on whether first-year effects continue to enhance resilience in later years. If seed folivory protection provided by relatively intact BSC discourages seed predation more than range drilled seeds is unknown.

While several studies confirm that fire can damage BSC structure and function (Johansen et al., 1982, 1984, 1998; Johansen 1993; West and Hassan 1985; Kasper 1994; Hilty et al. 2004), evidence also suggests BSCs exhibit some resistance to fire (Warren et al. 2015), especially large filamentous cyanobacteria (Johansen 2001). Previous studies also suggest live cyanobacterial recovery post-disturbance can occur relatively quickly (Belnap 1993). However, when no live cyanobacteria remains, pioneer bacteria in the phylum *Firmicute*, may take over and provide less benefit (e.g., continued soil stabilization benefit, but no nitrogen fixation, Aanderud, 2014). Long-term effects and successional stages with *Firmicute* are unknown and Aanderud's group will continue to monitor post-severe-fire BSC recovery.

The results from our greenhouse study suggest many future research directions. Perhaps the most intriguing are that the least developed BSC, often termed "bare soil," may indeed respond quite differently than actual bare soil. It is possible M2 may also be categorized in the field as "bare soil," yet this group behaved quite similarly to even the most developed BSC (M4) when minimum-till drilled. Are these two groups being range drilled because "there is no remaining BSC" when in fact cyanobacteria and nascent fungi/mosses/lichen could be providing essential support to plant establishment and inhibition of cheatgrass? These preliminary results seem compelling enough to justify further study.

Long-term site resilience may be more harmed than benefitted by surface disruption of BSC. Indeed, recent studies are beginning to indicate drilling strategies may not provide intended benefits (Arkle et al. 2014; Knutson et al. 2014). This pilot study supports the concept that BSC group may interact with drill seeding strategy on plant response. Applying a one-size fits all seeding strategy is likely ill-advised, especially as we learn more about the supporting role of BSC in these semi-arid landscapes. In restoration ecology, the context dependent nature of soils includes not only slope, rockiness, and compaction, but must also account for these intricate and diverse communities of biological soil crust.

Implications

Managers typically prefer to use drills to reduce seed herbivory and ensure seeds have good soil contact. However, on some of the least developed BSCs and/or in high wind areas, standard range drilling can have disastrous effects on soil erosion and seed retention, thus requiring other costly treatments and/or repeat treatments. On more developed BSCs, standard drilling provides a pulse of nutrients that can aid emergence, but if those plants fail, lack of intact BSCs could compound problems in subsequent years. As Great Basin temperatures increase and precipitation patterns change, both invasive species and wildfire severity/intensity/frequency are expected to increase. We are just beginning to evaluate post-wildfire restoration project success; previous seeding efforts seemed dependent on precipitation rather than any specific restoration strategies (Arkle et al. 2014; Knutson et al. 2014). Soil stabilization efforts of rehabilitation may also be negligible in many cases (Pyke et al. 2013). Restoration projects in the Great Basin face the significant challenge to decrease the frequency and intensity of disturbances (creating resistance prior to disturbance) as well as set the stage for resilience post-disturbance. Restoration projects that identify the most likely places and tools for success and the greatest impact on ecosystem services are essential.

In Chapters 2 and 3 I suggest that the realistic costs and benefits associated with incorporating new research results into post-wildfire projects need to be more directly addressed in publications. Following is an example of how cost-time-value assessments can be summarized, in this case with regard to incorporating or researching BSC assessments:

- Cost and time: Post-wildfire BSC accommodations may include: increased use of minimum-till drills and broadcast seeding, successional treatments, increased BSC assessment (time and personnel), increased assessment of species most likely to benefit from proposed seeding strategy based on BSC status.
- Value: Possible benefits of BSC accommodations may include increased buffering of droughts and floods (increased water holding capacity and plant available water), increased soil stability, increased exclusion of non-native species, decreased seed desiccation, and decreased predation by birds and small mammals.

Acknowledgments

Support for this project came from USDA-National Institute of Food and Agriculture and the Utah Agricultural Experiment Station (project #UTAO-1014). Additional thanks to Jessi Nelson for her help harvesting plants and Rebecca Mann for watering on occasion.

References

Aanderud, Z, 2014. Biological soil crusts and fire in Utah’s West Desert [Fact sheet]. In Desert Fire, Mammal, and Plant Studies. Available at: http://desert-fmp.org/wp-content/uploads/2014/06/Aanderud-fact-sheet.pdf (Accessed 15 March 2017).

Anderson, DC, Harper, KD, Holmgren, RC, 1982. Factors influencing development of cryptogamic soil crusts in Utah deserts. Journal of Range Management, 35, 180-185.

Arkle, RS, Pilliod, DS, Hanser, SE, Brooks, ML, Chambers, JC, Grace, JB, Wirth, TA, 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere, 5(3), 31.

Bashkin, M, Stohlgren, TJ, Osaki, Y, Lee, M, Evangelista, P, Belnap J, 2003. Soil characteristics and plant exotic species invasions in the Grand Staircase-Escalante National Monument, Utah, USA. Applied Soil Ecology, 22, 67–77.

Bates, D, Maechler, M, Bolker, B, Walker, S, 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48.

Belnap, J, 1993. Recovery rates of cryptobiotic crusts: inoculant use and assessment methods. Western North American Naturalist, 53(1), 89-95.

Belnap, J, 2001. Comparative structure of physical and biological soil crusts. In: Belnap, J, Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management, Springer-Verlag: Berlin, pp. 177-191.

Belnap, J, 2006. The potential roles of biological soil crusts in dryland hydrologic cycles. Hydrological processes, 20(15), 3159-3178.

Belnap, J, Büdel, B, Lange, OL, 2003. Biological soil crusts: characteristics and distribution. In: Belnap, J, Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management, Springer-Verlag: Berlin, pp. 3–30.

Belnap, J, Eldridge, D, 2003. Disturbance and recovery of biological soil crusts. In Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 363-383.

Belnap, J, Gardner, JS, 1993. Soil microstructure in soils of the Colorado Plateau: the role of the cyanobacterium Microcoleus vaginatus. Western North American Naturalist, 53(1), 40-47.

Belnap, J, Gillette, DA, 1997. Disturbance of biological soil crusts: impacts on potential wind erodibility of sandy desert soils in southeastern Utah. Land Degradation and Development, 8(4), 355-362.

Belnap, J, Gillette, DA, 1998. Vulnerability of desert biological soil crusts to wind erosion: the influences of crust development, soil texture, and disturbance. Journal of Arid Environments, 39(2), 133-142.

Belnap, J, Prasse, R, Harper, KT, 2001. Influence of biological soil crusts on soil environments and vascular plants. In Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 281-300.

Bowker, MA, Belnap, J, Rosentreter, R, Graham, B, 2004. Wildfire-resistant biological soil crusts and fire-induced loss of soil stability in Palouse prairies, USA. Applied Soil Ecology, 26(1), 41-52.

Brooks, ML, Matchett, JR, Shinneman, DJ, Coates, PS, 2015. Fire patterns in the range of greater sage-grouse, 1984-2013-Implications for conservation and management. Page 66. U.S. Geological Survey Open-File Report 2015-1167.

Brotherson, JD, Rushforth, SR, 1983. Influence of cryptogamic crusts on moisture relationships of soils in Navajo National Monument, Arizona. Western North American Naturalist, 43(1), 73-78.

Cameron, RE, 1966. Desert algae: soil crusts and diaphanous substrata as algal habitats. Jet Propulsion Lab Technical Report, 32–971, pp. 1–41.

Campbell, SE, Seeler, JS, Golubic, S, 1989. Desert crust formation and soil stabilization. Arid Land Research and Management, 3(2), 217-228.

Chaudhary, VB, Bowker, MA, O'Dell, TE, Grace, JB, Redman, AE, Rillig, MC, Johnson, NC, 2009. Untangling the biological contributions to soil stability in semiarid shrublands. Ecological Applications, 19(1), 110-122.

Cox, RD, Shaw, NL, Pellant, M, 2009. Ecology Society of America 94th Annual Meeting, Albuquerque, NM, August 5, 2009. Available at: http://esa.org/meetings_archive/2009/Paper18017.html and http://www.sagestep.org/events/esa_oos_09/Cox_RangelandRestoration.pdf (Accessed 16 March 2017).

D'Antonio, CM, Vitousek, PM, 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual review of ecology and systematics, 23, 63-87.

Davies, GM, Bakker, JD, Dettweiler-Robinson, E, Dunwiddie, PW, Hall, SA, Downs, J, Evans, J, 2012. Trajectories of change in sagebrush steppe vegetation communities in relation to multiple wildfires. Ecological Applications, 22, 1562-1577.

Dienes, L, Rosentreter, R, Eldridge, DJ, Serpe, MD, 2007. Germination and seedling establishment of two annual grasses on lichen-dominated biological soil crusts. Plant Soil, 295, 23–35

Eckert Jr, RE, Peterson, FF, Meurisse, MS, Stephens, JL, 1986. Effects of soil-surface morphology on emergence and survival of seedlings in big sagebrush communities. Journal of Range Management, 414-420.

Eldridge, DJ, Rosentreter, R, 1999. Morphological groups: a framework for monitoring microphytic crusts in arid landscapes. Journal of Arid Environments,41(1), 11-25.

Eldridge, DJ, Rosentreter, R. 2004. Shrub mounds enhance water flow in a shrub-steppe community in southwestern Idaho, USA. Seed and soil dynamics in shrubland ecosystems. Ogden, Utah: USDA Forest Service RMRS-P-31, 77-83.

Evans, RD, Johansen, JR, 1999. Microbiotic crusts and ecosystem processes. Critical Reviews in Plant Sciences, 18(2), 183-225.

Fierer, NG, Gabet, EJ, 2002. Carbon and nitrogen losses by surface runoff following changes in vegetation. Journal of Environmental Quality, 31(4), 1207-1213.

Freeman, ED, Sharp, TR, Larsen, RT, Knight, RN, Slater, SJ, McMillan, BR, 2014. Negative effects of an exotic grass invasion on small-mammal communities. PLoS One 9(9), e108843.

Friedmann, EI, Galun, M, 1974. Desert algae, lichens and fungi. Desert biology, 2, 165-212.

Friedmann, EI, Ocampo-Paus, RO, 1976. Endolithic blue-green algae in the Dry Valley: primary producers in the Antarctic Desert ecosystem, Science, 193, 1247–1249.

Garcia-Pichel, F, Belnap, J, 1996. Microenvironments and microscale productivity of cyanobacterial desert crusts. Journal of Phycology, 32(5), 774-782.

Germino, M, 2013. Dust, an emerging problem in the Great Basin: insights from 2012 Available at: http://environment.unr.edu/consortium/downloads/Presentations13/germino-gbc2-2013.pdf (Accessed 12 February 2016).

Gold, WG, Bliss, LC, 1995. Water limitations and plant community development in a polar desert. Ecology, 1558-1568.

Graaff, KA, Welty, J, Spaete, L, Dhakal, S, Baun, C, 2015. Quantifying and predicting fuels and the effects of reduction treatments along successional and invasion gradients in sagebrush habitats. Available at: https://www.firescience.gov/projects/11-1-2-30/project/11-1-2-30_final_report.pdf (Accessed 15 March 2017).

Harper, KT, Belnap, J, 2001. The influence of biological soil crusts on mineral uptake by associated vascular plants. Journal of Arid Environments,47(3), 347-357.

Harper, KT, Marble, JR, 1988. A role for nonvascular plants in management of arid and semiarid rangelands. In: Tueller, PT (Eds.), Vegetation science applications for rangeland analysis and management, Springer Netherlands, pp. 135-169.

Harper, KT, St. Clair, LL, 1985. Cryptogamic soil crusts on arid and semiarid rangelands in Utah: effects on seedling establishment and soil stability. Final report Bureau of Land Management, Utah State Office, Salt Lake City, 76 pp.

Hernandez, RR, Sandquist, DR, 2011. Disturbance of biological soil crust increases emergence of exotic vascular plants in California sage scrub. Plant Ecology, 212(10), 1709-1721.

Hilty, JH, Eldridge, DH, Rosentreter, R, Wicklow-Howard, M, 2003. Burning and seeding influence soil surface morphology in an Artemisia shrubland in southern Idaho. Arid Land Research and Management, 17, 111.

Hilty, JH, Eldridge, DJ, Rosentreter, R, Wicklow-Howard, MC, Pellant, M, 2004. Recovery of biological soil crusts following wildfire in Idaho. Rangeland Ecology and Management, 57(1), 89-96.

Howell, W, 1998. Germination and establishment of Bromus tectorum L. in relation to cation exchange capacity, seedbed, litter, soil cover and water. MS Thesis, Prescott College, AZ.

Jeffries, DL, Klopatek, JM, 1987. Effects of grazing on the vegetation of the blackbrush association. Journal of Range Management, 390-392.

Jenson, SL, 2011. USDA FS Shrub Sciences Lab: The development and use of forb species in restoration. In conference: Vegetation Resilience, the Role of the Perennial Herbaceous Understory, and Intact Sagebrush Workshop and Field Tour 24-25 May 2011 Winnemucca Convention Center Winnemucca, NV. Available at: http://greatbasin.wr.usgs.gov/gbrmp/docs/SD/The%20Development%20and%20Use%20of%20Forbs%20in%20Restoration.pdf. (Accessed 08 December 2015)

Johansen, JR, 1993. Cryptogamic crusts of semiarid and arid lands of North America. Journal of Phycology, 29(2), 140-147.

Johansen, JR, 2001. Impacts of fire on biological soil crusts. In: Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 385-397.

Johansen, JR, Ashley, J, Rayburn, WR, 1998. Effects of range fire on soil algal crusts in semiarid shrub-steppe of the lower Columbia Basin and their subsequent recovery. Western North American Naturalist, 53(1), 73-88.

Johansen, JR, Javakul, A, Rushforth, SR, 1982. Effects of burning on the algal communities of a high desert soil near Wallsburg, Utah. Journal of Range Management, 598-600.

Johansen, JR, St. Clair, LL, Webb, BL, Nebeker, GT, 1984. Recovery patterns of cryptogamic soil crusts in desert rangelands following fire disturbance. Bryologist, 238-243.

Kaltenecker, JH, 1997. The recovery of microbiotic crusts following post-fire rehabilitation on rangelands of the western Snake River Plain. Unpublished thesis, Boise State University, Boise, ID. 99 pp.

Kasper, KA, 1994. The effects of range fire and trampling upon algal soil crusts of a greasewood community in the West Desert of Utah. Doctoral dissertation, MS Thesis, John Carroll University, University Heights, Ohio.

Kleiner, EF, Harper, KT, 1977. Occurrence of four major perennial grasses in relation to edaphic factors in a pristine community. Journal of Range Management, 286-289.

Knapp, PA, 1996. Cheatgrass (Bromus tectorum L) dominance in the Great Basin Desert: History, persistence, and influences to human activities. Global Environmental Change, 6(1), 37-52.

Knutson, KC, Pyke, DA, Wirth, TA, Arkle, RS, Pilliod, DS, Brooks, ML, Chambers, JC, Grace, JB, 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. Journal of Applied Ecology, 51(5), 1414-1424.

Larsen, KD, 1995. Effects of microbiotic crusts on the germination and establishment of three range grasses. Unpubl. Thesis. Boise State University. Boise, ID.

Lenth, RV, 2016. Least-Squares Means: The R Package lsmeans. Journal of Statistical Software, 69(1), 1-33.

Maestre, FT, Huesca, M, Zaady, E, Bautista, S, Cortina, J, 2002. Infiltration, penetration resistance and microphytic crust composition in contrasted microsites within a Mediterranean semi-arid steppe. Soil Biology and Biochemistry, 34(6), 895-898.

Miller, ME, Bowker, MA, Reynolds, RL, Goldstein, HL, 2012. Post-fire land treatments and wind erosion–lessons from the Milford Flat Fire, UT, USA. Aeolian Research, 7, 29-44.

Morgan, JW, 2006. Bryophyte mats inhibit germination of non-native species in burnt temperate native grassland remnants. Biological Invasions, 8(2), 159-168.

Ostoja, SM, Schupp, EW, 2009. Conversion of sagebrush shrublands to exotic annual grasslands negatively impacts small mammal communities. Diversity and Distributions, 15(5), 863-870.

Ott, J, Shaw, NL, 2013. Seeding Native Plant Following Fire in Wyoming Big Sagebrush Shrub-steppe. Presentation, US Forest Service, Rocky Mountain Research Station, Boise, ID. Available at: http://www.fs.fed.us/rm/boise/research/shrub/projects/PowerPoint_Presentations/2013/Ott.pdf (Accessed 16 March 2017).

Pechanec, JF, Hull, AC, 1945. Spring Forage lost through cheatgrass fires. Nat. Wool Grower, 35, 13.

Pellant, M, 1990. The cheatgrass-wildfire cycle-are there any solutions? In: McArthur, ED, Romney, EM, Smith, SDm Tueller, PT, (compilers). Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 11-17.

Pellant, M, Shaver, P, Pyke, DA, Herrick, JE, 2000. Interpreting indicators of rangeland health. Version 3. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO., 111 pp.

Pellant, M, Shaver, P, Pyke, DA, Herrick, JE, 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO., 122 pp.

Pilliod, DS, 2015. Fire, rain, and post-fire restoration of sagebrush steppe in the Great Basin at Restoring the West conference, Oct 28-29 2015 Utah State University, Logan, UT.

Pilowsky, J, 2014. A Practical Guide to Mixed Models in R. Available at: http://ase.tufts.edu/gsc/gradresources/guidetomixedmodelsinr/mixed%20model%20guide.html (Accessed 12 February 2016).

Pyke, DA, Wirth, TA, Beyers, JL, 2013. Does Seeding After Wildfires in Rangelands Reduce Erosion or Invasive Species? Restoration Ecology, 21(4), 415-421.

Rau, BM, Blank, RR, Chambers, JC, Johnson, DW, 2007. Prescribed fire in a Great Basin sagebrush ecosystem: dynamics of soil extractable nitrogen and phosphorus. Journal of Arid Environments, 71(4), 362-375.

Rau, BM, Chambers, JC, Pyke, DA, Roundy, BA, Schupp, EW, Doescher, P, Caldwell, TG, 2014. Soil resources influence vegetation and response to fire and fire-surrogate treatments in sagebrush-steppe ecosystems. Rangeland Ecology and Management, 67(5), 506-521.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: URL https://www.R-project.org/.

Reynolds, R, Belnap, J, Reheis, M, Lamothe, P, Luiszer, F, 2001. Aeolian dust in Colorado Plateau soils: nutrient inputs and recent change in source. Proceedings of the National Academy of Sciences, 98(13), 7123-7127.

Rosentreter, R, 1994. Displacement of rare plants by exotic grasses. In: Monsen, SB, Kitchen, SG, (compilers). Proceedings of the ecology and management of annual rangelands. Gen. Tech. Rep. INT-GTR-313, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 170–175.

Serpe, MD, Orm, JM, Barkes, T, Rosentreter, R, 2006. Germination and seed water status of four grasses on moss-dominated biological soil crusts from arid lands. Plant Ecology, 185(1), 163-178.

Sharp, T, McMillan, B, 2014. Fire, small mammals, and plant rehabilitation [Fact sheet]. In: Desert Fire, Mammal, and Plant Studies. Available at: http://desert-fmp.org/wp-content/uploads/2014/06/Sharp-fact-sheet.pdf (Accessed 16 March 2017).

Shaw, N, Newingham, B, Ganguli, AC, Hild, AL, Cox, RD, Truax, J, Pellant, M, Pyke, D, Ogle, D, 2011. Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants. Final Report: JFSP Project Number 07-1-3-12. Boise, ID: Joint Fire Science Program. 30 pp.

Soil Quality Test Kit Guide, 2001. United States Department of Agriculture Agricultural Research Service (USDA ARS), Natural Resources Conservation Service, Soil Quality Institute. Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050956.pdf. (Accessed 14 December 2015)

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 2014. Web Soil Survey. Available at: http://websoilsurvey.nrcs.usda.gov/. (Accessed 16 March 2014).

St. Clair, LL, Johansen, JR, 1993. Introduction to the symposium on soil crust communities. Western North American Naturalist, 53(1), 1-4.

St. Clair, LL, Webb, BL, Johansen, JR, Nebeker, GT, 1984. Cryptogamic soil crusts: enhancement of seedling establishment in disturbed and undisturbed areas. Reclamation and Revegetation Research, 3.

Stamp, NE, 1984. Self-burial behaviour of Erodium cicutarium seeds. J Ecol, 72, 611–620.

Stark, RH, Toers, JL, Hafenrichter, AL, 1946. Grasses and cultural methods of reseeding abandoned farmlands in southern Idaho. Idaho Agri. Experiment Station Bulletin 267. 36 pp.

Stewart, G, Hull, AC, 1949. Cheatgrass (Bromus tectorum L.) - an ecologic intruder in southern Idaho. Ecology, 30, 58-74

Stohlgren, TJ, Otsuki, Y, Villa, CA, Lee, M, Belnap, J, 2001. Patterns of plant invasions: a case example in native species hotspots and rare habitats. Biological Invasions, 3(1), 37-50.

Stoof, CR, Wesseling, JG, Ritsema, CJ, 2010. Effects of fire and ash on soil water retention. Geoderma, 159, 276 – 285.

Tongway, D, Hindley, N, 2000. Assessing and monitoring desertification with soil indicators. In: Rangeland desertification. Springer Netherlands, pp 89-98.

Tyler, KJ, 2006. Biological soil crusts: Analysis of monitoring techniques at the Yakima Training Center, Washington. Doctoral dissertation, Central Washington University.

Warren, SD 2001. Synopsis: influence of biological soil crusts on arid land hydrology and soil stability. In Belnap, J, and Lange, OL (Eds.), Biological Soil Crusts: Structure, Function, and Management: Berlin, Springer-Verlag, pp. 349-360.

Warren, SD, St. Clair, LL, Johansen, JR, Kugrens, P, Baggett, LS, Bird, BJ, 2015. Biological Soil Crust Response to Late Season Prescribed Fire in a Great Basin Juniper Woodland. Rangeland Ecology and Management, 68(3), 241–247. http://doi.org/10.1016/j.rama.2015.03.007 (Accessed 15 March 2017).

West, NE, 1990. Structure and function of microphytic soil crusts in wildland ecosystems of arid and semi-arid regions. Advances in Ecological Research, 20, 179-223.

West, NE, Hassan, MA, 1985. Recovery of sagebrush-grass vegetation following wildfire. Journal of Range Management, 131-134.

Whisenant, SG, 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, ED, Romney, EM, Smith, SD, Tueller, PT, (compilers). Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 4-10.

Wieting, C, 2016. Quantifying soil hydraulic property changes with fire severity by laboratory burning. Doctoral dissertation, Colorado School of Mines. Arthur Lakes Library.

CHAPTER 5

STUDY IMPLICATIONS

All ecology is context dependent—and, of course, context variables multiply when we consider social-ecological complexities. There is no perfect model that will predict ecological resilience; there is no perfect model that will predict social-ecological resilience. This is not to say both ecology and social-ecological theory have not discerned highly predictive patterns, processes, and insights; simply to say social-ecological systems science will never enjoy the predictive capacity of physics or chemistry, for example.

In an attempt to accommodate social considerations into federal land management projects, including ecological restoration, the National Environmental Policy Act requires public comment periods. While they remain a critical requirement, current social-ecological theory and practice seem to suggest comment periods are not inclusive enough (Lee et al. 1995; Daniels and Walker 1996; Karkkainen 2002; United States Forest Service 2002). Additionally, as the number of wildfires and acres treated increase (Whisenant 1990; Pilliod and Welty 2013), public input on these vast areas of land is simultaneously decreasing due to categorical exclusions for post-wildfire rehabilitation. Subsequently, those communities experiencing the most risk may also be experiencing feelings of diminished perceived behavioral control and procedural justice. When modeling landscape connectivity, ignoring local community concerns and social-political factors managers and agencies must consider doesn't fit the reality scientists are trying to model (Meinke et al. 2009; Pyke et al. 2013; Arkle et al. 2014; Knutson et al. 2014). Nor do these models account for the social-ecological resilience opportunities these local communities could provide (Daniels and Walker 1996; Walker and Salt 2006; Cabin 2007; Palmer et al. 2007; Manning 2009; Coppock et al. 2015; McKinley et al. 2015). In other words, our current policy and research approaches to the social aspects of post-wildfire restoration projects most common across the Great Basin and Mojave Desert are not congruent with current social-ecological systems theory.

Collaborations seem to be the key to dialogue; comments on environmental impact statements provide some procedural justice, and should continue. But often projects that attract considerable public comment are subject to increased litigation pressure and obstruct project implementation (Daniels and Walker 1996; Wright 2010). Recognition of dialogue importance is evident in the increasing numbers of collaborations in science, management, and local governance. Admittedly, post-wildfire projects are likely to remain unfavorable to post-wildfire collaborations unless one or both of the following occur region wide: 1) Collaborations are organized before fires occur (potentially prioritized through GIS and risk modeling) and/or 2) post-wildfire agency policy drastically changes. In the meantime, studies such as this one can only hope to narrow social-ecological systems information gaps and make the argument for continued public and manager surveys (e.g., monitoring) and collaborations.

This dissertation approached post-wildfire restorations from a translational social-ecological framework using a cost-time-value lens. Post-wildfire restoration success in semi-arid shrublands has been historically difficult (Knapp 1996); increasing frequencies and severity of wildfires exacerbate this difficulty (Whisenant 1990). Despite the vast acres locally affected by wildfire, success of these post-wildfire rehabilitation projects is only recently being evaluated (Pyke et al. 2013; Arkle et al. 2014). In this dissertation, I argue that collaborations outside the formal NEPA process can facilitate post-wildfire social-ecological resilience; when a situation arises where a categorical exclusion is needed, local communities have already had a chance to make their views heard and would likely have a collaborative entity in place through which they could make their immediate concerns known as well. Encouraging active public dialogue about restoration projects may also ameliorate post-wildfire costs by providing opportunities both for extraneous funding for longer-term fire mitigation and reduced agency responsibilities. Studies that attempt to narrow the translational gap in post-wildfire projects may provide important insights, help public feel more engaged (simply by receiving a survey asking their opinion, or receiving an invitation to a workshop), and may help increase feelings in procedural justice and trust.

This dissertation provides an example of applying translational concepts in a collaboration-adverse social-ecological scenario. In these chapters, I explore coarse- and fine-scale social and ecological factors influencing post-wildfire restoration projects. Collectively, the first two chapters provides critical missing information between managers, researchers, and stakeholders. The third chapter presents research that explores one fine-scale factor, biological soil crusts, which may influence seeding success more than is commonly assumed.

In Chapter 2 I evaluated manager and public opinions of post-wildfire restoration projects. Interviews and structured surveys asked, “what do managers and the public think of post-wildfire projects,” “how do social variables compare with ecological variables when considering manager attitudes,” “do manager and public/taxpayer beliefs and attitudes align," what "norms and risk variables affect manager opinion," and "does policy support managerial considerations." I found that most managers felt projects are crucial, though a larger than expected percentage felt "the ecosystem will naturally heal itself"—this may suggest some frustration with current methods, which is validated by current research documenting lack of long-term "success," even when non-native species were used. Members of the public were also likely to support project implementation, and were generally much more supportive of projects and restoration techniques than managers perceived them to be. The discrepancy between what citizens believe and what managers think they believe could simply reflect that participants in NEPA processes tend to be from selected segments of society and not necessarily representative of constituents as a whole. Managers also tended to feel both involvement by both the public and interest groups creates barriers to project implementation, use of what managers considered "best science," and innovation adoption.

Lack of innovation (discussed more below) and project obstruction was not consistent with manager preferences *or* interested public preferences. This incongruence suggests the NEPA process alone is not sufficient to accommodate dialogue between agencies and the public. Additionally, managers' ecological attitudes were influenced by coarse- and fine-scale social, political, and ecological variables as well as perceived wildfire and climate risks. Policy, including and beyond time frame and funding limitations, was not considered by manager or public sectors to be supportive of managerial considerations. In other words, land managers do not develop their attitudes or make their decisions in a social-political vacuum; our current processes of involving public input does not seem to be eliciting opportunities for shared goals. Indeed, our results highlighted social-political variables are critical to our understanding of land management decisions in the Great Basin. Communicating project goals through positive messaging (re: habitat and forage versus invasive grasses) and focusing climate dialogue on precipitation events may be important translational components at the start of collaborations.

In Chapter 2 I assessed manager interest and attitudes toward post-wildfire research. Did the managers value the research conducted by members of our research team? Which research were managers most able or willing to consider in post-wildfire projects? Who were the managers that were most able or willing to consider new research results (aka early innovators)? Managers (and public) supported the incorporation of experimental research techniques into post-wildfire projects, but managers' ability and/or willingness to consider specific research varied by region. Managers were most likely to be able/willing to consider fertile island research results in post-wildfire rehabilitations compared to other research presented. Mid-career managers tended to have more positive attitudes toward research. Generalist range managers involved in post-wildfire projects were more likely than fire-specific managers to express interest and positive attitudes toward the research presented. These types of results highlight the context-dependent nature of social-ecological systems and the additional cost-time-value constraints fire specific managers' likely experience. Managers' ability/willingness to consider research results' application in post-wildfire projects tended to decrease in association with social and political variables even though public surveys supported both current methods and experiments. Collaborations can help identify shared goals more readily than traditional unidirectional information methods that transfer information from scientists to managers or public, but not vice versa.

I am not suggesting researchers should not research what they are interested in. For example, despite higher response rates to BSC in the surveys compared to other research, it is still probably unlikely that members of the public, nor Great Basin managers for that matter, would initially be very interested in biological soil crust. Indeed, it is possible higher response rates were simply due to survey fatigue regarding later research questions. However, in a collaboration setting, I, who very much would like to study BSC, can implement what I have learned from this study. “Biological soil crusts,” I can say, “buffer these dry systems from *droughts* and *floods*. They continue to provide *benefits* after many wildfires, including *soil stabilization* and increasing available water for *forage* and *habitat*. Intact BSC may even exclude some *invasive species*, helping to prevent *future wildfires*.” Essentially I can propose my study using terms that may resonate more effectively with both land managers and the interested public. By presenting a research idea to end-users and asking for approval, procedural justice and trust may be bolstered. If they are not interested, other avenues can of course be explored for the research. But BSC shouldn’t be included and/or prioritized in an on-the-ground post-wildfire project if there is no current local or manager interest in it.

In Chapters 2 and 3 I make the argument that effective translational ecology and diffusion of innovations both require iterative feedbacks at every stage of research development. As a manager-researcher-public collaboration was not possible for this project, I explored BSC attitudes and potential ecological importance from three directions. In Chapter 2 I asked managers in semi-structured interviews how and if they consider BSC in their post-wildfire decisions. In Chapter 3 I assessed manager attitudes toward BSC research with the translational framework and CTV lens. In Chapter 4 I conducted a pilot study assessing if damage to BSC sustained through restoration treatment influences restoration seedling establishment. I continue to explore the social context of BSC in a conjoint choice experiment (not included in this dissertation) that includes BSC to determine relative influences of social, political, and ecological variables on specific decision-making scenarios (e.g., seeding strategy and native vs. non-native seed selection).

Not surprisingly, Chapter 2 indicated willingness/ability to consider BSC was more likely in the Mojave Desert compared to managers working in the Great Basin. Managers with increased climate risks and *more* social-political pressures were also more likely to think BSCs matter. However, managers' personal wildfire risk perceptions (both past experiences with wildfire and perceived risk of future wildfire near personal property) were not related to BSC opinion. Preliminary results from the conjoint choice experiment suggest BSC presence (as well as all other social-political-ecological variables included) may have very little influence on seeding strategy preference, although further exploration of characteristics still need to be evaluated (e.g., region). Nonetheless, rather than reflecting on BSC alone, the lack of association of BSC with wildfire, and lack of social-political-ecological influence on seeding strategy, suggests land managerial tendencies toward blanket strategies regardless of different levels of social-political variables or ecological variables (including invasive species abundance). Indeed, one preferred strategy is far easier to accomplish under tight deadlines, while new methods are risky and difficult to incorporate. In other words, the reward system in a large bureaucracy works contrary to innovation.

Our results from the greenhouse pilot study indicated establishment of some commonly used restoration species, especially forbs, may not be enhanced significantly by the initial disturbance and consequent nutrient pulse provided by range drilling. Results were suggestive that minimum-till drilling may support improved emergence across a range of species and BSC groups, and field trials can be recommended. As expected, more developed BSC seemed to support increased emergence across native species. Contrary to other studies, cheatgrass emergence was not significantly inhibited by BSC presence, likely due to ideal greenhouse conditions. Whether burning the BSC was part of this result requires follow up field trials. Overall this study seems to suggest the loss of BSC hydrological and soil stabilization properties due to destruction by standard range drilling may diminish long-term, and possibly even short-term, restoration goals. Given recent studies highlighting project success reliance on hydrological properties (Arkle et al. 2014; Knutsen et al. 2014) and soils (Rau et al. 2014), field studies that further investigate the possible contributes of BSC groups to this dynamic in different levels of wildfire affected projects can be recommended.

Our results suggest the current method of public lands post-wildfire rehabilitation is not able to consider new science effectively. Additionally, these time-constrained managers are not accurately predicting what local communities want from post-wildfire projects. Encouraging greater public collaboration could help alleviate this, both by increasing managers’ comfort with using new science results and by reducing some perceptions of social barriers. Increasing time frames for proposal submission would help managers incorporate innovations on projects, but is unlikely to address the self-efficacy and/or social barrier perceptions likely to accompany new methods. Collaboration partnerships may be able to create a variety of plan frameworks they agree with and that reflect the best new science, so that managers can still get credible submitted within current short and competitive time frames. Collaborations may also provide opportunities for alleviating monetary considerations and increasing ecological stewardship.

Restructuring project goal messaging may assist agencies and managers hoping to engage more effectively with local communities. Workshops, local meetings, and citizen science projects can decrease unidirectional flows of information and increase public procedural justice. Modeling efforts that account for social components of both proposed and past restoration projects will likely be more robust than those lacking these components. As we strive to mitigate wildfire and improve ecosystem services, it is becoming apparent that social components must be accounted for to achieve regional success. When we recognize bridging political boundaries (e.g., private and state lands) is critical to large-scale ecosystem resilience, the value of increasing dialogue and trust becomes clear. In conclusion, post-wildfire collaborations between managers, researchers, and local communities are likely key to building the social-ecological resilience of Great Basin and Mojave Desert ecosystems.

References

Arkle, RS, Pilliod, DS, Hanser, SE, Brooks, ML, Chambers, JC, Grace, JB, Wirth, TA, 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere, 5(3), 31.

Cabin, RJ, 2007. Science-Driven Restoration: A Square Grid on a Round Earth? Restoration Ecology, 15(1), 1-7.

Coppock, DL, Fernández-Giménez, M, Hiernaux, P, Huber-Sannwald, E, Schloeder, C, Valdivia, C, Arrendondo, J, Jacobs, M, Turin, C, and Turner, M, 2015. Rangelands in developing nations: conceptual advances and societal implications. In: Briske, D (Ed.), Rangeland Systems: Processes, Management, and Challenges. Springer.

Daniels, SE, Walker, GB, 1996. Collaborative learning: improving public deliberation in ecosystem-based management. Environmental impact assessment review, 16(2), 71-102.

Karkkainen, BC, 2002. Toward a smarter NEPA: monitoring and managing government's environmental performance. Columbia Law Review, 102, 903-972.

Knapp, PA, 1996. Cheatgrass (Bromus tectorum L) dominance in the Great Basin Desert: History, persistence, and influences to human activities. Global Environmental Change, 6(1), 37-52.

Knutson, KC, Pyke, DA, Wirth, TA, Arkle, RS, Pilliod, DS, Brooks, ML, Chambers, JC, Grace, JB, 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. Journal of Applied Ecology, 51(5), 1414-1424.

Lee, B, Haworth, L, Brunk, C. 1995. Values and science in impact assessment. *Environments* 1995;23(1): 93 – 100.

Manning, C, 2009. The psychology of sustainable behavior: Tips for empowering people to take environmentally positive action. Minnesota Pollution Control Agency.

McKinley, DC, Miller-Rushing, AJ, Ballard, HL, Bonney, R, Brown, H, Evans, DM, French, RA, Parrish, JK, Phillips, TB, Ryan, SF, Shanley, LA, 2015. Investing in citizen science can improve natural resource management and environmental protection. Issues in Ecology, 19.

Meinke, CW, Knick, ST, Pyke, DA, 2009. A spatial model to prioritize sagebrush landscapes in the Intermountain West (USA) for restoration. Restoration Ecology 17(5):652-659.

Palmer, M, Allan, JD, Meyer, J, Bernhardt, ES, 2007. River restoration in the twenty-first century: data and experiential knowledge to inform future efforts. Restoration Ecology, 15(3), 472-481.

Pilliod, DS, Welty, JL, 2013. Land treatment digital library. U.S. Geological Survey Data Series 806. http://dx.doi.org/10.3133/ds806 PRISM Climate Group. 2011. Gridded climate.

Pyke, DA, Wirth, TA, Beyers, JL, 2013. Does Seeding After Wildfires in Rangelands Reduce Erosion or Invasive Species? Restoration Ecology, 21(4), 415-421.

Rau, BM, Chambers, JC, Pyke, DA, Roundy, BA, Schupp, EW, Doescher, P, Caldwell, TG, 2014. Soil resources influence vegetation and response to fire and fire-surrogate treatments in sagebrush-steppe ecosystems. Rangeland Ecology and Management, 67(5), 506-521.

United States Forest Service (USFS). 2002. The process predicament: how statutory, regulatory, and administrative factors affect national forest management. U.S. Forest Service, Washington, D.C., USA.

Walker, B, Salt, D, 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Washington, DC, USA: Island Press. 174 pp.

Whisenant, SG, 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, ED, Romney, EM, Smith, SD, Tueller, PT, (compilers). Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 4-10.

Wright, V, 2010. Influences to the success of fire science delivery: perspectives of potential fire/fuels science users. USDA Forest Service, Rocky Mountain Research Station, Final Report to the Joint Fire Science Program, JFSP Project, pp. 04-4.

APPENDICES

APPENDIX A

POST-WILDFIRE MANAGER INTERVIEW GUIDE

Section A: Relevant Demographics

1. Circle if interviewee is Male Female
2. What is the highest level of education you have completed?

   ____
3. How long have you been in your current position? ____________________ years
4. How long have you been working in land management within the Mojave Desert?

   Great Basin? ________________________ years
5. How long have you lived in the community where you now work?

   _______________years
6. Approximately what proportion of your time is spent doing administrative tasks vs. working in the field? ___________% office/ _____________ % field

   b. Does this change in the summer? How much?

Section B: General Questions About Post-wildfire Decisions

1. How would you describe your role in the decision-making process about restoration and rehabilitation activities after wildfire?
2. Do you feel you are adequately funded to restore or rehabilitate how you'd like to all the wildfires within your jurisdiction? Why/why not?
3. Is there a "standard" protocol for post-fire restoration in your jurisdiction? If so, can you describe it, please?

4. What, if any, are the factors that might cause you to have to vary your response from the standard protocol?
5. Sometimes managers must make tradeoffs between various goals of a restoration project. What are some of the most common trade-offs you have to decide between?

Section C: Ecological Factors in Post-wildfire Decisions

1. What are the most important ecological (biological, edaphic, etc) factors in your decision-making process?
2. How do you weigh the tradeoff between native and non-native species when choosing the plant species used in a re-seeding project?
3. To what extent do you typically weigh the local climate when choosing what to plant?

   b. How does future climate figure into your decision process?
4. To what extent do you typically weigh pre-fire vegetation condition when choosing what to plant? Do you use reference sites, ESDs, other?

   b. How does pre-fire vegetation condition figure into your decision process?
5. To what extent do you typically weigh soil, slope, and geological factors when choosing what to plant?

   b. How do these edaphic factors figure into your decision process?
6. To what extent do you typically weigh biological soil crust when choosing rehabilitation techniques (probes: mastication, bulldoze, seeding with: aerial, drill, no-till, min-till, etc)

b. How does BSC figure into your decision process? C. If not answered before, what types of equipment do they have at their disposal?

7. What are the primary considerations that influence your decisions about the *timing* of post-fire restoration activities?
8. What other factors typically influence your choices about plant species and timing of reseeding activities?
9. Are dust storms or dust-related events a concern in the areas you work in? Have they changed in frequency or intensity? Which direction?

   b. If so, why are they a concern? If not, if dust-related events became an issue in your area, what would be your biggest concern about them as a manager?

   c. What are the biggest drivers of dust-related events in your landscapes?

   d. Do you foresee yourself ever having to make dust-related management decisions? How important would dust management be to you in comparison to other post-wildfire variables?

Section D: Stakeholder Role in Post-wildfire Decisions

1. Do you feel the trade-off decisions you make are the same as those that would be made by the primary stakeholders in your jurisdiction? Why/why not?
2. Do you believe the local and/or regional public has any interest in post-wildfire restoration projects?
3. What aspects of post-wildfire restoration projects do you think the public have the most potential to be interested or concerned about?

4. Have you experienced situations where outside pressure has been applied to influence decisions about post-fire restoration, either from elected officials in local, state, or national offices or from agency offices at the state, regional or Washington office level? If you're comfortable discussing this situation, what can you tell us about it?
5. Is there anything you would like to add?

APPENDIX B

POST-WILDFIRE MANAGER SURVEY

Online survey implemented by SurveyMonkey Inc.

Wildfires threaten both homes and the rangelands that many of us depend on. We need your responses! Your answers can help agencies understand if their policy after a wildfire is effective, and guide researchers' future questions to be the most relevant to you.

Page 1: General Demographics

1. What is your age? *N* = 254, 99% response rate

22 to 39	40 to 59	60 or older
37%	57%	6%

2. What is your gender? *N* = 254, 99% response rate

28%	Female
72%	Male

3. What is the highest level of education you have completed? *N* = 252, 98% response rate

Some college	Graduated from college	Some graduate school	Completed graduate school
19%	44%	16%	21%

4. How long have you lived in your community? *N* = 255, 99.6% response rate

< 5 years	5 to 9 years	10 to 15 years	> 15 years
29%	20%	22%	30%

5. How long have you lived in the Mojave Desert and/or Great Basin? *N* = 253, 99% response

< 5 years	5 to 9 years	10 to 15 years	> 15 years
14%	14%	18%	54%

6. In what type of community do you live? *N* = 255, 99.6%

77%	Small town or rural area
23%	Large town or metropolitan area

Page 2: Job Characteristics

7. What is your current profession? Compressed. Job titles often don't mention fire necessarily, or managerial vs ecological responsibilities (supervisory technician vs wildfire ecologist) *N* = 255, 99.6%

	Manager	Non-manager	Total
Fire-specific	16%	18%	34%
General Ecology	25%	41%	66%

8. How long have you been working in post-wildfire landscapes? *N* = 237 (19 NA), 93%

1 to 5 years	6 to 10 years	11 to 15 years	> 15 years
16%	20%	15%	48%

9. How long have you been working in the Mojave Desert and/or Great Basin? *N*=239, 93%

1 to 5 years	6 to 10 years	11 to 15 years	> 15 years
14%	25%	21%	40%

10. About how long have you been in your current position? *N* = 242, 95%

< 1 year	1 to 5 years	6 to 10 years	11 to 15 years	> 15 years
5%	46%	26%	16%	8%

11. What agency/company and/or region do you work for? *N* = 256, 100%

77%	Bureau of Land Management
17%	National Park Service
6%	Forest Service

12. What region do you primarily work in? $N = 256$, 100%

67%	Great Basin
23%	Mojave Desert
10%	Southern Great Basin

13. What state do you primarily work in? $N = 256$, 100%

22%	ID	16%	OR
21%	NV	16%	CA
14%	UT	11%	AZ

14. In a typical year your work is primarily: $N = 242$, 95%

14%	In the field
39%	In the office
47%	About equal

15. What is your role in the decision-making process post-wildfire? (Check all that apply) $N = 225$, 89%

17%	Collect data
59%	Compile report (draft and/or evaluate report [may collect data too])
24%	Make final decision

Page 3: Personal Wildfire Experience

In this study we will be comparing the perceptions and experience of fuels management professionals with those of citizens in the region. The next few questions relate to aspects of your life outside of your work and are designed for comparative purposes.

16. About how far is it from your house to a natural area that might burn? $N = 236$, 92%

< 1 mile	1-5 miles	5-10 miles	> 10 miles
57%	27%	12%	4%

17. If any wildfires have occurred close to your home, how many miles away was the fire from your house? *N* = 236, 92%

< 1 mile	1-5 miles	5-10 miles	> 10 miles	No wildfires have occurred this close to my house
17%	36%	22%	12%	12%

18. If you answered yes to question 17, how long ago did that wildfire occur? *N* = 219, 86%

< 5 years	5-10 years	> 10 years	N/A
71%	18%	3%	7%

19. In your opinion, how would you rate the likelihood that a wildfire could break out in the natural land within 10 miles of your home in the next 5 years? *N* = 233, 91%

Very Unlikely	Unlikely	Likely	Very Likely
6	11	88	128
3%	5%	38%	55%

20. About how often do you spend non-work related time on lands managed primarily for recreation such as state or national parks? *N* = 236, 92%

Never	Rarely	Yearly	Monthly	At least weekly
1%	9%	19%	45%	25%

21. About how often do you spend non-work time on multiple-use rangelands? *N* = 236, 92%

Never	Rarely	Yearly	Monthly	At least weekly
1%	6%	15%	48%	30%

Page 4: Context

For the following questions, it is important for us to understand the context of the decisions you have to make.

22. Do the time frames for submitting rehabilitation plans post-wildfire containment provide adequate time to assess a site and develop an effective strategy? *N* = 233, 91%

Never	Usually not	Neutral	Usually	Always	*N*/A
4%	31%	18%	36%	4%	7%

Modelled	Time frames not adequate	Chi.Sq.	DF	p-value
Boruta	Role – do more than collect data	31.316	6	0
Boruta	Time frames change proposals	79.092	6	0
Boruta	Precise policy isn't realistic	34.241	6	0
Boruta	Prioritize severity over visibility	6.548	3	0.088
Boruta	IG are concerned about projects	23.21	9	0.006
Boruta	BSC is a better indicator of soils	46.087	9	0
Boruta	Halogeton control likely	20.189	9	0.017
Boruta	Trend more tenured post-wildfire	6.9736	6	0.3233
Boruta	Trend more tenured region	7.2966	6	0.2943
Boruta	Future wildfire risk similar	2.7572	6	0.8386
	More recent past wildfire	29.199	9	0.001
	More frequent NP/St. recreation	26.765	12	0.008
	More frequent rangelands recreation	36.814	12	0
	Funding changes proposal	50.71	6	0
	Public think sites can naturally heal	11.171	6	0.083
	Locals are not concerned projects	26.169	9	0.002
	Larger public are not concerned	23.835	9	0.005
	Locals don't agree with decisions	16.302	9	0.061
	General policy is unrealistic	50.473	9	0
	Support experimental research	56.596	9	0
	Drought/floods split	63.636	9	0
	Temperatures are a concern	55.077	9	0
	Halogeton is a concern	25.087	9	0.003

23. How often do you change the initial proposal based on ecosystem characteristics that may have been missed in the time-frame allowed? *N* = 232, 91%

Never	Rarely	About half the time	Almost every time	Every time	N/A
1%	37%	26%	10%	2%	24%

Modelled	Time frame cause changes	Chi.Sq.	DF	p-value
Boruta	Younger managers	4.9	2	0.08638
Boruta	Shorter regional tenure	10	3	0.01557
Boruta	State	6	5	0.3053
Boruta	I think sites can naturally heal	4.8688	2	0.08765
Boruta	Shorter regional residency	6.4	3	0.09532
Boruta	Region, possibly SGB	1.5	1	0.217
Boruta	Role – data collectors	38.713	4	0
Boruta	Time frames are inadequate	79.092	6	0
Boruta	Funding changes proposals	97.895	4	0
Boruta	IG precise policy is realistic	18.656	4	0.001
Boruta	BSC over veg	49.727	6	0
Boruta	Halogeton request funding	22.026	6	0.001
	Type (Fire-specific NA)	6.184	2	0.045
	More field/equal time	8.415	4	0.078
	More frequent NP recreation	16.003	8	0.042
	IG think projects are crucial	16.901	4	0.002
	Public NA crucial/heal	20.035	4	0
	Precise policy is unrealistic	19.427	4	0.001
	Public precise policy	8.707	4	0.069
	Changes = split natives/non, never changes = non-natives	7.081	2	0.029
	Locals are not concerned projects	13.246	6	0.039
	Larger public not concerned	13.884	6	0.031
	Netural/dk IG concerned projects	20.774	6	0.002
	Opinion if locals agree decisions	12.908	6	0.045
	In general policy is unrealistic	42.347	6	0
	Support experimental research	21.476	6	0.002
	Drought/floods are a concern	19.404	6	0.004
	Temperatures neutral (never change, not a concern)	16.733	6	0.01
	Pollinator-based seed selection	20.173	10	0.028
	Halogeton is not a concern	11.45	6	0.075
	Less halogeton herbicide	13.05	6	0.042

24. How often do you have to cut back the initial proposal based on funding allocated? *N* = 231, 90%

Never	Rarely	About half the time	Almost every time	Every time	N/A
0.4%	10%	27%	29%	12%	21%

	Funding causes proposal changes	Chi.Sq.	DF	p-value
Boruta	Work_region	10.732	6	0.097
Boruta	Agency (90% in each agency)	13.52	4	0.009
Boruta	Role (nearly identical)	18.89	4	0.001
Boruta	Risk_fire_10mi_5y	12.167	6	0.058
Boruta	Time frames inadequate	50.71	6	0
Boruta	Time frames cause proposal changes	97.895	4	0
Boruta	Less uncertain public think crucial/heal	12.244	4	0.016
Boruta	IG precise policy unrealistic	17.641	4	0.001
Boruta	Native pref, didn't answer*	14.972	2	0.001
Boruta	Larger public concern/split*	13.393	6	0.037
Boruta	Support experimental research*****	29.304	6	0
Boruta	Drought/flood concern*****	19.972	6	0.003
Boruta	Halogeton is a concern*	11.566	6	0.072
Boruta	State (ID most, OR least)	18.0939	15	0.2578
Boruta	Public precise policy unrealistic	3	2	0.1778
Boruta	More likely to choose small mammal response actions	10	6	0.116
	MD least likely changes, most likely NA	12.534	4	0.014
	IG think science-based	9.628	4	0.047
	Prioritize livestock	7.32	2	0.026
	Neutral/split local concern	16.162	6	0.013
	IG are concerned	13.914	6	0.031
	Locals agree with decisions/neutral	12.202	6	0.058
	General policy is unrealistic	14.682	6	0.023
	Funding change/split Temperatures Funding never changes, disagree/neutral Temps	13.544	6	0.035
	BSC useful split, funding rarely changes, not useful	12.754	2	0.002
	Rarely changes, Veg over BSC	13.052	6	0.042
	Rarely changes, pollinators don't	16.946	10	0.076

	matter			
	Funding constraint to krat seed	19.851	8	0.011
	Halogeton request funding	20.201	6	0.003

Page 5: Opinions

This section can help us understand how manager opinions relate to citizen and stakeholder opinions. Check one for EACH group (I, Interest Group, Public).

25. Project effectiveness:

Post-wildfire projects are crucial to site rehabilitation
The ecosystem will naturally heal itself
Don't Know

	DK	Naturally heal	Projects crucial
I think ($N = 223$, 87%)	9% (21)	14% (32)	76% (170)
IG think ($N = 223$, 87%)	21% (53)	35% (90)	31% (80)
Public think ($N = 221$, 86%)	35% (78)	35% (77)	30% (66)

	I think projects are crucial	Chi.Sq.	DF	p-value
Boruta	Age < 60 years	25.181	4	0
Boruta	Longer regional tenure = opinion	11.484	6	0.075
Boruta	Agency = FS naturally heal	10.63	4	0.031
Boruta	IG think naturally heal	26.443	4	0
Boruta	Public think naturally heal	18.672	4	0.001
Boruta	IG concerned about projects	16.79	6	0.01
Boruta	Locals don’t agree with decisions	20.224	6	0.003
Boruta	Science-based projects (check)	43.126	4	0
Boruta	Gender = female	4.5226	2	0.1042
Boruta	Type	0.6786	2	0.7123
Boruta	Less regional tenure	4.601	6	0.5959
Boruta	Region, GB	4.6986	4	0.3196
Boruta	Halogeton is a concern	9.4	6	0.1507
Boruta	Longer post-fire tenure = opinion	6.5682	6	0.3626
	State, AZ naturally heal	17.477	10	0.064
	Precise policy = split	46.972	4	0
	More likely to work in the office	7.796	4	0.099
	Local concern projects = project opinion	39.617	6	0
	Larger public concern = project opinion	17.444	6	0.008

	General policy neutral	17.071	6	0.009
	Support experiments	27.141	6	0
	Drought/floods are a concern	26.581	6	0
	Temperatures are a concern	22.925	6	0.001
	Less likely to increase krat seed	16.53	8	0.035
	Small mammals less herbicide halogeton	10.725	6	0.097

	Interest groups projects crucial	Chi.Sq.	DF	p-value
Boruta	Age < 60	11.441	4	0.022
Boruta	< 5 and > 15 years regional resident	22.852	6	0.001
Boruta	I think naturally heal	26.443	4	0
Boruta	Public thinks naturally heal	50.843	4	0
Boruta	IG think precise policy is unrealistic	23.049	4	0
Boruta	IG think science is unrealistic	43.76	4	0
Boruta	IG concerned projects	14.616	6	0.023
Boruta	Local are concerned	27.997	6	0
Boruta	BSC over Veg	14.952	6	0.021
	Shorter work tenure	13.639	6	0.034
	Agency = NPS	9.327	4	0.053
	Region = GB	12.94	4	0.012
	IG nat heal, less rangelands recreation	16.767	8	0.033
	Time frames cause proposal changes	16.901	4	0.002
	Precise policy is unrealistic	16.107	4	0.003
	Public_think_policy_precise_not_dk	11.658	4	0.02
	Science-based	7.797	4	0.099
	Public science-based	18.825	4	0.001
	Natives (also when DK IG)	5.66	2	0.059
	Larger public are concerned	15.045	6	0.02
	Locals don’t agree with decisions	21.362	6	0.002
	Temperatures are changing	11.368	6	0.078
	Fertile islands don’t matter	16.205	10	0.094
	Excluding kangaroo rats doesn’t matter	21.215	8	0.007
	Less concerned about Halogeton	11.696	6	0.069

	Public projects crucial	Chi.Sq.	DF	p-value
Boruta	Supervisor Manager	5.788	2	0.055
Boruta	Shorter wildfire tenure	17.739	6	0.007
Boruta	Agency = FS	17.051	4	0.002
Boruta	Role = final decisions	11.124	4	0.025
Boruta	Time frames	11.171	6	0.083
Boruta	Funding	12.244	4	0.016
Boruta	Crucial heal	18.672	4	0.001

Boruta	Local are not concerned	20.25	6	0.002
Boruta	IG naturally heal	50.843	4	0
Boruta	Public policy precise	31.654	4	0
Boruta	Public science realism	50.525	4	0
Boruta	Work current	12.504	8	0.1301
Boruta	Least risk of fire to home			
Boruta	Rangelands recreation	4.6613	6	0.5879
Boruta	BSC vs veg	5.3	6	0.5044
	Lived in community least and most	13.886	6	0.031
	Time frame change proposal	20.035	4	0
	Precise policy	11.792	4	0.019
	IG precise policy	16.579	4	0.002
	IG science realism	9.424	4	0.051
	Prioritize severity political	5.581	2	0.061
	Larger public is concerned	11.564	6	0.072
	BSC are not useful	5.026	2	0.081
	Kangaroo rats are a nuisance	13.722	8	0.089

26. Agency policy:

Post-wildfire projects should strive to follow agency policy precisely
Post-wildfire agency policy does not always fit specific situations in my area
Don't Know

	DK	Precise policy always	Policy doesn't always fit
I think ($N = 237, 93\%$)	17 (8%)	41 (18%)	169 (74%)
IG think ($N = 224, 88\%$)	93 (42%)	71 (32%)	60 (27%)
Public think ($N = 222, 87\%$)	132 (60%)	18 (8%)	72 (32%)

	Manager policy opinion (precise)	Chi.Sq.	DF	p-value
Boruta	Male	9.207	2	0.01
Boruta	Larger metropolitan areas	4.831	2	0.089
Boruta	Time frames are sufficient	34.241	6	0
Boruta	Science-based	21.829	4	0
Boruta	Sites can naturally heal	46.972	4	0
Boruta	More likely to prioritize visibility	6.341	2	0.042
Boruta	Policy is realistic	60.863	6	0
Boruta	Halogeton concerned	20.517	6	0.002
Boruta	Small mammals response	23.581	14	0.051

Boruta	Fire specific manager	1	2	0.5927
Boruta	Funding doesn’t cause proposal changes	6.5	4	0.1646
Boruta	Don’t need to increase seed for kangaroo rats	15	8	0.0631
Boruta	Don’t need to exclude kangaroo rats	14	8	0.07037
	Longer tenure post-wildfire	12.057	6	0.061
	Longer regional tenure	13.011	6	0.043
	Field Office	9.074	4	0.059
	More frequent state/NP recreation	14.902	8	0.061
	Rangelands recreation	36.178	8	0
	Time frames don’t cause proposal changes	19.427	4	0.001
	IG naturally heal	16.107	4	0.003
	Public crucial heal	11.792	4	0.019
	IG precise policy unrealistic	19.601	4	0.001
	IG science is often unrealistic	15.393	4	0.004
	Prioritize short-term/ more acres	5.793	2	0.055
	Local are not concerned	29.81	6	0
	Larger public is concerned	29.625	6	0
	IG concern or not	16.638	6	0.011
	Locals agree or disagree	21.505	6	0.001
	Support experiments split	29.705	6	0
	Drought/floods neutral	29.863	6	0
	Temperatures	29.892	6	0
	BSC vs vegetation loss neutral	26.656	6	0
	Fertile islands are important, $ barrier	18.52	10	0.047
	Kangaroo rats nuisance sometimes	20.685	8	0.008
	Don’t currently control halogeton	15.885	6	0.014
	Don’t adapt halogeton herbicide/ neutral	16.973	6	0.009

	IG policy opinion: (precise)	Chi.Sq.	DF	p-value
Boruta	Non-supervisors	4.777	2	0.092
Boruta	Agency (BLM)	18.135	4	0.001
Boruta	Time frames don’t change proposals	18.656	4	0.001
Boruta	Funding doesn’t change proposals	17.641	4	0.001
Boruta	Public precise policy	76.723	4	0
Boruta	IG want projects to be science-based	69.097	4	0
Boruta	Larger public is not concerned	30.434	6	0
Boruta	IG are not concerned	18.846	6	0.004
Boruta	Locals agree with decisions	18.761	6	0.005
Boruta	General policy is unrealistic	24.667	6	0

Boruta	Pollinator seed selection is not important	21.591	10	0.017
	Region = GB/SGB	10.476	4	0.033
	Live farther from potential fire risk area	16.426	6	0.012
	IG policy unrealistic = crucial, precise = split	23.049	4	0
	Public projects are crucial	16.579	4	0.002
	Precise policy is unrealistic	19.601	4	0.001
	Public science is realistic	19.918	4	0.001
	Prioritize annual grass over livestock	7.221	2	0.027
	Accept non-native species use	5.26	2	0.072
	Locals concern neutral/split	13.043	6	0.042
	Don’t control halogeton	12.497	6	0.052
	Don’t adapt Halogeton herbicide	10.937	6	0.09

	Public policy opinion (precise)	Chi.Sq.	DF	p-value
Boruta	Longest regional tenure	10.749	6	0.096
Boruta	Public thinks sites can naturally heal	31.654	4	0
Boruta	IG want precise policy followed	76.723	4	0
Boruta	IG want science-based projects	26.396	4	0
Boruta	Public want science-based projects	68.989	4	0
Boruta	More likely to adapt halogeton herbicide	27.706	6	0
	Agency	7.74	4	0.1014
	Funding change proposal	6.2	4	0.182
	Lived in region longer	6.61	6	0.3583
	Time frames change proposals = split	8.707	4	0.069
	IG think naturally heal	11.658	4	0.02
	Age > 60	9.562	4	0.048
	Locals are concerned	12.112	6	0.06
	Locals disagree with decisions	15.066	6	0.02
	BSC vs vegetation loss = split	14.805	6	0.022
	More likely to control halogeton	12.03	6	0.061

27. Science:

Project choices should be based on proven scientific research
Science often doesn't reflect reality on the ground in a particular management situation
Don't Know

	DK	Science based	Doesn't reflect reality
I think ($N = 226, 88\%$)	17 (8%)	72 (32%)	137 (61%)
IG think ($N = 222, 87\%$)	62 (28%)	117 (53%)	43 (19%)
Public think ($N = 219, 86\%$)	108 (49%)	41 (19%)	70 (32%)

	Managers prefer science-based	Chi.Sq.	DF	p-value
Boruta	Agency = NPS	9.532	4	0.049
Boruta	Precise policy	21.829	4	0
Boruta	IG science does not often fit	22.946	4	0
Boruta	Prefer and DK science, IG concerned	12.85	6	0.045
Boruta	Locals do not agree with decisions	14.676	6	0.023
Boruta	Kangaroo rats are a nuisance	18.193	8	0.02
Boruta	Severity versus livestock split	2.03	2	0.3625
	Age 40-59 years	7.854	4	0.097
	Gender = Male	4.732	2	0.094
	Less regional tenure until >15 years	10.816	6	0.094
	More likely to work in the field	14.207	4	0.007
	Projects are crucial	43.126	4	0
	IG projects crucial	7.797	4	0.099
	Native species	7.668	2	0.022
	Best tool over more acres	7.678	2	0.022
	Local concern projects = neutral	28.415	6	0
	Larger public concern = neutral	16.053	6	0.013
	General policy is realistic	13.814	6	0.032
	Don't support experiments (low *N*)	31.537	6	0
	Drought/floods, split	32.037	6	0
	Temperatures are a concern/neutral	32.379	6	0
	BSC are useful	4.657	2	0.097
	BSC for soil stability assessment	14.972	6	0.02
	Fertile islands adapt	25.203	10	0.005
	Halogeton concerned	16.285	6	0.012
	Halogeton less likely to control (low *N*)	12.616	6	0.05

	IG science-based	Chi.Sq.	DF	p-value
Boruta	IG prefer naturally heal	43.76	4	0
Boruta	Public think crucial	9.424	4	0.051
Boruta	IG precise policy	69.097	4	0

Boruta	I don't think science often fits	22.946	4	0
Boruta	Public want science-based*	40.269	4	0
	State = UT and OR	16.21	10	0.094
	Funding causes proposal changes	9.628	4	0.047
	I think policy often doesn't fit	15.393	4	0.004
	Public precise policy	26.396	4	0
	Choose non-native species	7.504	2	0.023
	Locals are concerned/neutral	17.665	6	0.007
	Larger public are not concerned	22.783	6	0.001
	IG not concerned/neutral	15.753	6	0.015
	Locals agree with decisions	16.49	6	0.011
	Policy is unrealistic	17.249	6	0.008
	Less likely to increase seed kangaroo rats	19.527	8	0.012

	Public science-based	Chi.Sq.	DF	p-value
Boruta	Managers with higher degrees	12.443	6	0.053
Boruta	DK public science, public naturally heal	50.525	4	0
Boruta	Public want precise policy	68.989	4	0
Boruta	IG want science-based	40.269	4	0
	Age (> 60)	9.069	4	0.059
	Supervisors	5.572	2	0.062
	Type (General range managers)	6.383	2	0.041
	Role (compile report)	11.148	4	0.025
	Closer to a past wildfire	15.959	8	0.043
	IG think projects are crucial	18.825	4	0.001
	IG want precise policy	19.918	4	0.001

Page 6: Trade-Off Decisions

For each pair of trade-off choices below, please check the choice you believe should receive higher priority and/or the choice you agree with the most.

28. I would prioritize: $N = 223$, 87%

6%	Locations where the public will see treatments on a regular basis.
94%	Locations where the post-wildfire ecosystem effect is the most severe.

	Visibility	Chi.Sq.	DF	p-value
Boruta	Precise policy	6.341	2	0.042

Boruta	Prioritize livestock	6.073	1	0.014
Boruta	Political pressure over severity	33.331	1	0
Boruta	Small mammal response doesn't matter	15.307	7	0.032
	Primarily work in the field	6.579	2	0.037
	Monthly park recreation	8.511	4	0.075
	Monthly rangelands recreation	19.613	4	0.001
	Time frames are sufficient	6.548	3	0.088

29. I would prioritize: $N = 219$, 86%

78%	A site with high invasion of cheatgrass or red brome (and more likelihood of wildfire)
22%	A site with lower invasion of cheatgrass or red brome, but more use by domestic livestock

	Livestock	Chi.Sq.	DF	p-value
Boruta	Agency = BLM/FS	5.972	2	0.05
Boruta	Primarily work in the field	8.183	2	0.017
Boruta	More frequent rangelands recreation	9.979	4	0.041
Boruta	Prioritize visibility	6.073	1	0.014
	Lived region	1.2	3	0.7515
	Work region	0.6	3	0.8974
	I think crucial/DK	0.25	2	0.8832
	Funding causes proposal changes	7.32	2	0.026
	IG think policy doesn't often fit	7.221	2	0.027

30. I would choose: $N = 220$, 86%

53%	Reseeding with natives, even if it costs more
47%	Reseeding with the species most likely to become established, even if non-native

	Choose native species	Chi.Sq.	DF	p-value
Boruta	Agency = NPS	38.942	2	0
Boruta	Region = Mojave Desert	30.975	2	0
Boruta	State = AZ/CA	15.543	5	0.008
Boruta	Least and most educated	11.418	3	0.01
Boruta	< 10 years regional resident	20.941	3	0
Boruta	More frequent state/np recreation	16.249	4	0.003
Boruta	Funding causes changes/dk	14.972	2	0.001
Boruta	Longer monitoring	11.258	1	0.001
Boruta	Local are concerned	6.617	3	0.085

Boruta	Temperatures are changing	15.775	3	0.001
Boruta	BSC are useful	18.187	1	0
Boruta	Pollinator-based seeds are important	9.913	5	0.078
Boruta	Increase seed based on kangaroo rats	10.259	4	0.036
Boruta	Larger public concern DK	4.6	3	0.2069
	Gender = Female	7.703	1	0.006
	< 10 years regional tenure	15.928	3	0.001
	< 1 mile and > 5 miles from past wildfire	9.71	4	0.046
	Time frames cause changes	7.081	2	0.029
	IG think projects are crucial/dk	5.66	2	0.059
	DK IG policy precision	5.26	2	0.072
	I prefer science-based projects	7.668	2	0.022
	IG think science doesn't fit	7.504	2	0.023
	Prioritize best tool	3.082	1	0.079
	Locals disagree with decisions/neutral	16.44	3	0.001
	Policy is realistic/neutral	11.776	3	0.008
	BSC is a better indicator of soil stability	10.426	3	0.015
	Slightly more concerned about Halogeton	10.935	3	0.012
	Slighlty more likely to control Halogeton	7.287	3	0.063

31. I would prioritize: $N = 219$, 86%

39%	Short-term spending (1-3 years) as an effective means to restore lands
61%	Long-term spending (5-8 years) to ensure effective rehabilitation, even if it means less acreage can be covered

	Shorter-term spending	Chi.Sq.	DF	p-value
Boruta	Agency = FS	6.824	2	0.033
Boruta	Actual fire home	9.25	4	0.055
Boruta	Prioritize acres over tools	10.563	1	0.001
Boruta	Increasing seed kangaroo rats doesn't matter	12.758	4	0.013
	Accept non-native species	11.258	1	0.001
	Age > 60 years	4.5	2	0.1043
	Slightly more field	2.1	2	0.3416
	Actual fire years	3	3	0.3867
	Sites should naturally heal	1.3	2	0.5124
	IG science opinion; longer term DK	2.7	2	0.257
	Public science opinion	1.8	2	0.4078

	College degree /some graduate	6.669	3	0.083
	Precise policy	5.793	2	0.055
	Don’t support experiments	6.503	3	0.09
	BSC are not useful	5.06	1	0.024
	Pollinator seed selection doesn’t matter	10.361	5	0.066

32. I would prioritize: $N = 223$, 87%

4%	Sites deemed important by political pressure
96%	Sites where the post-wildfire ecosystem effect is the most severe

*Since $N = 9$ is so low, statistics should be viewed with caution.

	Prioritize political pressure sites	Chi.Sq.	DF	p-value
Boruta	Community = urban	4.502	1	0.034
Boruta	More rangelands recreation	24.895	4	0
Boruta	Prioritize visibility	33.331	1	0
Boruta	State = UT	3.5	5	0.625
Boruta	> 10 miles from fire risk	3.9	3	0.2684
	Locals agree with decisions/dk/neutral	7.323	3	0.062
	BSC vs vegetation loss DK/neutral	9.302	3	0.026
	Fire-specific manager	3.387	1	0.066
	Agency = BLM	4.736	2	0.094
	More state/NP recreation	14.68	4	0.005
	Public think crucial	5.581	2	0.061

33. I would prioritize: $N = 221$, 86%

71%	Using the most effective tool, even if it means we can't treat as many acres
29%	Using the tools that allow us to cover the most acres, even if those tools aren't always ideal

	Prioritize best tools	Chi.Sq.	DF	p-value
Boruta	< 15 years regional resident	7.48	3	0.058
Boruta	Longer term spending	10.563	1	0.001
Boruta	Non-supervisor	0.031	1	0.8608
Boruta	Future wildfire likely	4.1	3	0.2476
Boruta	Time frames opinion	1.5	2	0.483
Boruta	Funding is sufficient	2.8	2	0.2499
Boruta	Visibility may be important	2	1	0.1535
Boruta	Severity over livestock	0.66	1	0.416
	Some college/graduate degree	9.789	3	0.02
	Equal time in office and field	5.477	2	0.065

	Science is realistic	7.678	2	0.022
	Native species preference	3.082	1	0.079
	More likely to adapt herbicide Halogeton	7.148	3	0.067

Page 7: Public

34. Post-wildfire project concern:

	Disagree	Neutral	Agree	Don't Know
1. The local community is not concerned about post-wildfire projects in my area (*N* = 225, 88%)	75%	11%	12%	3%
2. The larger public is not concerned about post-wildfire projects in my area (*N* = 224, 88%)	38%	6%	36%	6%
3. Outside interest groups are not concerned about post-wildfire projects in my area (*N* = 224, 88%)	68%	13%	12%	7%
4. The local community agrees with the majority of post-wildfire treatment decisions (*N* = 225 , 88%)	20%	28%	40%	11%

	Local community not concerned	Chi.Sq.	DF	p-value
Boruta	Lived region	15.344	9	0.082
Boruta	Region = MD	20.521	6	0.002
Boruta	State = NV	26.265	15	0.035
Boruta	Lower future wildfire risk	20.119	9	0.017
Boruta	Less frequent rangelands recreation	31.958	12	0.001
Boruta	Larger public not concerned	163.243	9	0
Boruta	Crucial/heal split	39.617	6	0
Boruta	IG crucial	27.997	6	0
Boruta	Public naturally heal	20.25	6	0.002
Boruta	IG not concerned	155.876	9	0
Boruta	Locals agree decisions	53.016	9	0
Boruta	Policy realistic	57.008	9	0
Boruta	Temperatures changing (locals concerned = neutral temperatures/disagree)	80.982	9	0
Boruta	Pollinator-based seed selection	33.109	15	0.005
Boruta	Increase seed based on kangaroo rats	24.716	12	0.016

Boruta	Agency = NPS	10	6	0.1191
Boruta	Farther past wildfire	14	9	0.1339
	Older age, local community more concern	11.148	6	0.084
	Time frames inadequate (check)	26.169	9	0.002
	Time frames cause changes (check)	13.246	6	0.039
	Funding cause changes (check)	16.162	6	0.013
	Policy precise	29.81	6	0
	IG policy precise	13.043	6	0.042
	Public precise policy doesn't fit	12.112	6	0.06
	Science split	28.415	6	0
	IG science often unrealistic/dk	17.665	6	0.007
	Native species preferred	6.617	3	0.085
	Support experiments split	82.105	9	0
	Drought/floods split	72.673	9	0
	Vegetation loss over BSC	37.82	9	0
	Halogeton concern split	21.939	9	0.009
	Control halogeton	17.009	9	0.049
	Don't adapt Halogeton herbicide	19.972	9	0.018

	Larger public is not concerned	Chi.Sq.	DF	p-value
Boruta	Lived region	20.591	9	0.015
Boruta	Region = SGB/MD	15.169	6	0.019
Boruta	State = OR	23.251	15	0.079
Boruta	Past fire far away	21.819	12	0.04
Boruta	IG precise policy	30.434	6	0
Boruta	Local public is concerned	163.243	9	0
Boruta	IG not concerned	87.897	9	0
Boruta	Concerned, policy unrealistic	48.633	9	0
Boruta	Temperatures are not changing	40.144	9	0
Boruta	Agency = FS	4.3	6	0.6338
Boruta	Increase seed for kangaroo rats	12	12	0.4236
	Time frames inadequate	23.835	9	0.005
	Time frame change proposals	13.884	6	0.031
	Funding change proposals	13.393	6	0.037
	Projects crucial	17.444	6	0.008
	IG naturally heal	15.045	6	0.02
	Public naturally heal	11.564	6	0.072
	Precise policy doesn't fit	29.625	6	0
	Science doesn't fit (neutral lpc = science)	16.053	6	0.013
	Larger public concerned, science-	22.783	6	0.001

	based			
	Locals agree with decisions	52.766	9	0
	Support experiments	36.949	9	0
	Drought/floods are are changing	44.839	9	0
	Vegetation loss better than BSC	23.509	9	0.005
	Fertile islands don’t matter	31.31	15	0.008
	Halogeton not a concern	19.609	9	0.02

	IG are not concerned	Chi.Sq.	DF	p-value
Boruta	Lived region < 5/10-15 years	18.353	9	0.031
Boruta	More years since fire	17.477	9	0.042
Boruta	Time frames adequate	23.21	9	0.006
Boruta	IG precise policy	18.846	6	0.004
Boruta	Locals not concerned	155.876	9	0
Boruta	Larger public not concerned	87.897	9	0
Boruta	Policy realism split	29.764	9	0
Boruta	Vegetation loss over BSC	28.778	9	0.001
	Agency = NPS/neutral	1.5	6	0.9564
	Region = MD	6.2	6	0.4047
	Public precise policy doesn’t fit	9.2	6	0.1637
	Don’t change seed based on kangaroo rats	18	12	0.1151
	Some college/some graduate school	15.318	9	0.083
	Regional tenure 1-5 and 11-15 years	15.109	9	0.088
	Time frame change proposal	20.774	6	0.002
	Funding rarely change proposal	13.914	6	0.031
	Crucial/heal split	16.79	6	0.01
	IG projects crucial	14.616	6	0.023
	Policy precision split	16.638	6	0.011
	Science-based	12.85	6	0.045
	IG science doesn’t fit	15.753	6	0.015
	Locals agree with decisions	62.697	9	0
	Support experiments	34.66	9	0
	Drought/floods not concerned	42.627	9	0
	Temperatures not concerned	34.792	9	0
	Fertile islands don’t matter	28.643	15	0.018
	Kangaroo rats are a nuisance	18.977	12	0.089
	Don’t change Halogeton herbicide	16.549	9	0.056

	Locals disagree with decisions	Chi.Sq.	DF	p-value
Boruta	Age youngest and oldest*	18.596	6	0.005
Boruta	Community*	6.589	3	0.086

Boruta	Field primarily*	14.907	6	0.021
Boruta	Projects are crucial*	20.224	6	0.003
Boruta	Temperatures slight concern/split*	25.727	9	0.002
Boruta	Vegetation is better than BSC*	23.812	9	0.005
Boruta	Fertile islands split*	29.368	15	0.014
Boruta	Kangaroo rats and seed split*	20.659	12	0.056
Boruta	Shorter community residency	8.2	9	0.5123
Boruta	Mid-range post-fire tenure	8.7	9	0.4652
Boruta	Mid-range regional tenure	10	9	0.3403
Boruta	Region	9.7	6	0.1379
	> 10 years since a nearby fire	15.732	9	0.073
	Yearly rangeland recreation	30.606	12	0.002
	Time frames not sufficient	16.302	9	0.061
	Time frame changes split	12.908	6	0.045
	Funding rarely causes changes	12.202	6	0.058
	IG think crucial	21.362	6	0.002
	Precise policy doesn’t fit	21.505	6	0.001
	IG think policy doesn’t fit	18.761	6	0.005
	Public prefer precise policy	15.066	6	0.02
	Science-based	14.676	6	0.023
	IG sciences doesn’t fit	16.49	6	0.011
	Native species preferred	16.44	3	0.001
	None prioritized political pressure	7.323	3	0.062
	Local concerned	53.016	9	0
	Larger public concerned	52.766	9	0
	IG concerned	62.697	9	0
	Policy is unrealistic	26.975	9	0.001
	Don’t support experiments	21.895	9	0.009
	Drought/floods slightly concern/split	22.649	9	0.007
	Halogeton concern split	15.359	9	0.082

35. Ecosystems:

	Disagree	Neutral	Agree	NA
1. Official post-wildfire agency policy is sometimes opposed to what makes sense for specific ecosystems. (*N* = 223, 87%)	11%	31%	54%	4%
2. I support experimental post-wildfire treatments that science suggests may work in the ecosystem, but haven't been directly tested yet (*N* = 224, 88%)	6%	11%	81%	2%

3. Ecosystems near where I work are in danger due to drought and/or flood potential ($N = 224$, 88%	8%	12%	79%	2%
4. Ecosystems near where I work are in danger due to long-term shifts in local temperatures ($N = 224$, 88%)	18%	25%	56%	2%

	General policy is realistic	Chi.Sq.	DF	p-value
Boruta	Policy precise	60.863	6	0
Boruta	Larger public not concerned	48.633	9	0
Boruta	IG concerned split	29.764	9	0
Boruta	Veg over BSC	47.402	9	0
Boruta	DK halogeton herbicide	19.4	9	0.022
	5-9 years regional tenure	16.786	9	0.052
	Agency = FS (BLM least)	18.616	6	0.005
	Increased fire risk	18.442	9	0.03
	Monthly NP recreation	38.934	12	0
	Less frequent rangelands recreation	20.984	12	0.051
	Time frames are long enough	50.473	9	0
	Time frames don’t change proposal	42.347	6	0
	Funding doesn’t change proposal	14.682	6	0.023
	Naturally heal	17.071	6	0.009
	IG policy doesn’t fit	24.667	6	0
	Science based	13.814	6	0.032
	IG science doesn’t fit	17.249	6	0.008
	Prefer native species	11.776	3	0.008
	Local concern projects	57.008	9	0
	Locals agree decisions	26.975	9	0.001
	Do not support experimental research	100.526	9	0
	Drought/floods not a concern	100.969	9	0
	Temperatures concern, neutral policy	102.633	9	0
	BSC_patchy	35.884	9	0
	Kangaroo rats not a nuisance	19.291	12	0.082
	Halogeton neutral/concerned	18.121	9	0.034
	Don’t control Halogeton split/neutral	20.391	9	0.016

	Do not support experiments	Chi.Sq.	DF	p-value
Boruta	Less future wildfire risk	24.826	9	0.003
Boruta	Funding doesn’t change proposals	29.304	6	0
Boruta	Projects are crucial (0 naturally heal)	27.141	6	0
Boruta	Precise policy split	29.705	6	0

Boruta	Drought/floods not a concern/neutral	235.68	9	0
Boruta	Pollinators don’t matter	42.399	15	0
Boruta	None control halogeton	14.921	9	0.093
Boruta	Fertile islands don’t matter, $	13	10	0.2167
Boruta	Unlikely to control kangaroo rats	14	10	0.321
	Farther from most recent wildfire	15.526	9	0.077
	Less frequent state/NP recreation	30.668	12	0.002
	Less frequent rangelands recreation	53	12	0
	Time frames are sufficient	56.596	9	0
	Time frames don’t change proposal	21.476	6	0.002
	Science opinion split	31.537	6	0
	Prioritize more acres for years	6.503	3	0.09
	Locals are not concerned projects	82.105	9	0
	Larger public is concerned projects	36.949	9	0
	IG are not concerned projects	34.66	9	0
	Locals don’t agree with decisions	21.895	9	0.009
	Policy is realistic	100.526	9	0
	Temperatures not a concern/neutral	226.537	9	0
	BSC not useful	9.621	3	0.022
	Veg over BSC	43.118	9	0
	Halogeton not a concern	15.733	9	0.073

	Precipitation **not** a concern	Chi.Sq.	DF	p-value
Boruta	Gender = males only*	11.546	3	0.009
Boruta	Funding doesn’t change proposal*	19.972	6	0.003
Boruta	Larger public is concerned*	44.839	9	0
Boruta	Do not support experiments*	235.68	9	0
Boruta	Temperatures*	255.185	9	0
Boruta	IG science opinion	2	4	0.7323
Boruta	State = ID	13	10	0.2328
Boruta	Region = GB	13	10	0.2328
Boruta	Public think crucial	5.7	4	0.2243
Boruta	Fertile islands split	7.5	10	0.6794
Boruta	Exclude kangaroo rats split	10	8	0.2525
	5-10 years since a nearby fire	16.716	9	0.053
	Less state/NP recreation	33.669	12	0.001
	Less rangelands recreation	50.256	12	0
	Time frames are sufficient	63.636	9	0
	Time frames don’t change proposal	19.404	6	0.004
	Split. Neutral = projects crucial.	26.581	6	0
	Precise policy	29.863	6	0
	Science split	32.037	6	0

	Local concern = neutral	72.673	9	0
	IG not concerned	42.627	9	0
	Locals agree decisions	22.649	9	0.007
	Policy realistic	100.969	9	0
	Veg over BSC	48.103	9	0
	Increasing seed for kangaroo rats doesn't matter	21.732	12	0.041

	Temperatures are not a concern: /N = same for neutral, N opp = neutral opposite	Chi.Sq.	DF	p-value
Boruta	Community = rural/N*	6.444	3	0.092
Boruta	Agency = BLM (FS N)*	31.339	6	0
Boruta	Region = GB (SGB N)*	25.757	6	0
Boruta	Less NP recreation*	46.413	12	0
Boruta	Science doesn't fit/N*	32.379	6	0
Boruta	Non-native species/N*	15.775	3	0.001
Boruta	Locals not concerned/N*	80.982	9	0
Boruta	Don't Support experiments/N*	226.537	9	0
Boruta	Drought/floods*	255.185	9	0
Boruta	BSC not useful/N*	22.311	3	0
Boruta	Vegetation over BSC/N*	48.528	9	0
Boruta	Pollinators don't matter/N*	26.085	15	0.037
Boruta	Kangaroo rats are a nuisance/N*	23.653	12	0.023
Boruta	Increase seed kangaroo rats doesn't matter/N*	22.127	12	0.036
Boruta	Age > 60/N	3	4	0.5495
Boruta	Local are not concerned	10	6	0.1245
Boruta	Science doesn't fit/N	4.1	4	0.3946
Boruta	Halogeton concern/N opp	5.1	6	0.5276
	Fire-specific = neutral	6.676	3	0.083
	Most rangelands recreation/N	49.552	12	0
	Time frames sufficient/neutral/N opp	55.077	9	0
	Time frame don't change proposal/N opp	16.733	6	0.01
	Funding doesn't change proposal/N	13.544	6	0.035
	Naturally heal/N	22.925	6	0.001
	IG naturally heal/N	11.368	6	0.078
	Policy doesn't fit/N	29.892	6	0
	Larger public not concerned/N	40.144	9	0
	IG not concerned projects/N	34.792	9	0
	Locals agree with decisions/N	25.727	9	0.002

	Policy split/N	102.633	9	0

Page 8: Ecological Study Results

The questions on the following pages are prefaced with a short summary of our preliminary ecological research results. For the purpose of this study, please assume all results remain consistent with the preliminary results over time. This will help us determine the context of our study implications and help guide our future research.

Page 9: Biological Soil Crust

Central Great Basin: Intense fire resulted in loss of Biological Soil Crust, decreased N-fixation, water infiltration, and soil stability. After just 2 years, soil stability is starting to return.
Mojave Desert: Trends are difficult to see in the short-time frame so far; while soil stability is returning, soils remain much less stable than the Central Great Basin soils 2 years post-fire.

36. Check one: (*N* = 208, 81%)

58%	When applying for funding post-wildfire, assessing Biological Soil Crust (BSC) could help us assess hydrology and soil stability faster
42%	Our present methods are accurate and sufficient without assessing BSC

37. Rate:

	Disagree	Neutral	Agree	NA
1. Vegetation loss is a more reliable indicator of soil stability than Biological Soil Crust. (*N* = 219, 86%)	20%	35%	37%	9%
2. Biological Soil Crust can only establish if there are source propagules from a patchy, non-intense fire. (*N* = 216, 84%)	17%	45%	25%	13%

	BSC useful	Chi.Sq.	DF	p-value
Boruta	Shorter regional residency	17.919	3	0
Boruta	Funding changes proposal	12.754	2	0.002
Boruta	Agency = NPS (BLM least)	13.004	2	0.002
Boruta	Region = MD (SGB least)	11.145	2	0.004
Boruta	Science-based	4.657	2	0.097
Boruta	Prefer native species	18.187	1	0
Boruta	Prioritize longer-term spending	5.06	1	0.024
Boruta	BSC over vegetation	49.279	3	0

Boruta	Pollinator based seed selection	19.06	5	0.002
Boruta	Halogeton control	8.749	3	0.033
	Less years since nearby fire	1.7	2	0.4275
	IG projects are crucial	3.9	2	0.1447
	IG policy doesn't fit	2.6	2	0.2707
	Public precise policy	0.64	2	0.7276
	Adapt Halogeton herbicide	6.2	3	0.1029
	Shorter regional work tenure	11.761	3	0.008
	Role = data collectors	5.579	2	0.061
	More frequent state/NP recreation	9.203	4	0.056
	Least frequent rangelands recreation	9.137	4	0.058
	Public naturally heal	5.026	2	0.081
	Support experiments	9.621	3	0.022
	Temperatures are a concern	22.311	3	0

	Prefer BSC assessment for soil stability	Chi.Sq.	DF	p-value
Boruta	Least/most educated	15.803	9	0.071
Boruta	Community = urban	8.618	3	0.035
Boruta	Role = data collectors	22.944	6	0.001
Boruta	Time frames insufficient	46.087	9	0
Boruta	Science based	14.972	6	0.02
Boruta	Native species preferred	10.426	3	0.015
Boruta	Prioritize severity vs political split	9.302	3	0.026
Boruta	Local concerned projects	37.82	9	0
Boruta	IG are concerned	28.778	9	0.001
Boruta	BSC is useful	49.279	3	0
Boruta	Kangaroo rats are a nuisance	23.125	12	0.027
	State = ID	8	10	0.626
	6-10 years post-fire tenure	12.8425	9	0.1699
	Shorter regional residency	9.4	6	0.1545
	IG science doesn't fit	1.2	4	0.8848
	Respond to small mammals, many Rx	17	14	0.2678
	Gender = Female	6.7	3	0.082
	Type = general range manger	9.424	3	0.024
	Monthly state/NP recreation	27.085	12	0.008
	Monthly rangelands recreation	21.979	12	0.038
	Time frame change proposal	49.727	6	0
	Funding change proposal	13.052	6	0.042
	IG think crucial	14.952	6	0.021
	Policy precise	26.656	6	0
	Public policy split	14.805	6	0.022
	Larger public concerned	23.509	9	0.005

Locals don't agree with decisions	23.812	9	0.005
General policy often doesn't fit	47.402	9	0
Support experiments	43.118	9	0
Drought/floods less of a concern	48.103	9	0
Temperatures are a concern	48.528	9	0
Fertile islands are important	41.263	15	0
Pollinator-based seed selection	45.585	15	0
Halogeton is a concern	18.781	9	0.027
Halogeton control	39.024	9	0
Adapt halogeton herbicide	21.044	9	0.012

****Patchy Biological Soil Crust can only establish if there are source propagules from a patchy, non-intense fire.We included this question to ask if bsc rehabilitation is considered essentially futile or necessary after an intense fire? This question wasn't clear enough to managers – answers were too scattered for analysis and it was omitted.

Page 10: Red Brome / Pollination Strategies – Mojave Desert

Red Brome: October red brome germination events seem to give this invasive a head start. Fire positively affected seed production. Precipitation, fine soils, and fertile islands also positively affected seed productions. Additionally, multiple fires at one location resulted in faster red brome invasion post-fire event.

Pollination: The more specialized pollination strategy a plant has, the worse fire was for its reproductive viability.

38. What affects red brome invasion the most on your landscapes? (Rank: 1 least, 6 most)

	Least					Most		
	1	2	3	4	5	6	DK	Mean
Fire	24%	7%	6%	2%	6%	11%	43%	**2.88**
Month of fire	12%	16%	10%	10%	5%	5%	41%	**2.94**
Precipitation	9%	21%	9%	5%	8%	7%	39%	**3.07**
Temperature	4%	7%	20%	17%	8%	5%	38%	**3.54**
Soil texture	4%	5%	10%	19%	17%	3%	41%	**3.82**
Fertile islands	8%	5%	6%	6%	13%	19%	42%	**4.18**

*These were omitted from analysis – Fire should rank high, but here it looks like it ranks as the least important. Similar pattern with precipitation. Question may have been misinterpreted by many.

39. Presence of fertile islands would influence how we reseed spatially (Check all that apply) (N = 203, 79%)

Absolutely	If we had the money	If we had the time	If we had money and time	I don't think it matters	I don't know
27%	14%	7%	17%	7%	28%

	Fertile islands response	Chi.Sq.	DF	p-value
Boruta		140.01		
	Pollinator-based seed*	2	25	0
Boruta	5-10 years community resident*	22.378	15	0.098
Boruta	Community = rural*	10.026	5	0.074
Boruta	Monthly rangelands recreation*	30.843	20	0.057
Boruta	Locals don’t agree decisions split*	29.368	15	0.014
Boruta	BSC vs Vegetation split*	41.263	15	0
Boruta	Increase seed based on kangaroo rats split*	49.515	20	0
Boruta	5-10 years regional resident*	19	15	0.2364
Boruta	State = CA (UT&ID doesn’t matter)*	24	25	0.525
Boruta	Most recent fire*	13	15	0.6352
Boruta	Region = GB/MD (SGB doesn’t matter)*	12	10	0.2699
Boruta	Closer to fire risk area*	21	15	0.1412
Boruta	BSC are useful*	6.7	5	0.2435
	Kangaroo rats are not a nuisance	32.13	20	0.042
	Halogeton is a concern	27.389	15	0.026
	Halogeton request control	24.09	15	0.064
	More risk of future fire split	37.391	15	0.001
	IG projects crucial	16.205	10	0.094
	Policy precise	18.52	10	0.047
	Science-based	25.203	10	0.005
	Larger public concerned/neutral	31.31	15	0.008
	IG concerned	28.643	15	0.018

40. If a wildfire is patchy in nature, I would prioritize seed from species that are pollinated by specialist insects and let the wind-pollinated and less specialized species reseed on their own. (Check all that apply) (*N* = 201, 79%)

Absolutely	If we had the money	If we had the time	If we had money and time	I don't think it matters	I don't know
15%	13%	12%	14%	14%	30%

Pollinator-based seed selection	Chi.Sq.	DF	p-value

Region = MD (SGB/dm)*	20.993	10	0.021
BSC is useful*	19.06	5	0.002
BSC over vegetation*	45.585	15	0
Adapt to fertile islands*	140.012	25	0
Increase seed when kangaroo rats*	65.308	20	0
Exclude kangaroo rats*	35.75	20	0.016
Supervisor split (dm = not supervisor)	4.4	5	0.4881
Primarily work in the office (equal dm)	13	10	0.2351
Education = some college/graduate degree	23.128	15	0.081
State = CA (UT dm)	36.543	25	0.064
Time frame doesn’t change proposal	20.173	10	0.028
Funding doesn’t change proposal	16.946	10	0.076
IG policy doesn’t fit	21.591	10	0.017
Prefer native species	9.913	5	0.078
Prioritize spending split (short-term dm)	10.361	5	0.066
Locals are not concerned	33.109	15	0.005
Support experiments/neutral	42.399	15	0
Temperatures are a concern	26.085	15	0.037
Kangaroo rats are a nuisance (dm split)	28.53	20	0.097
Halogeton not a concern (dm same)	42.649	15	0
Halogeton control split (dm don’t control)	32.25	15	0.006
Adapt herbicide split (dm don’t adapt)	31.797	15	0.007

Page 11: Small Mammals

1. Burning shifted Mojave Desert small mammal population to kangaroo rat dominance. K-rats selectively predate native plant species.
2. Small mammals presence suppresses Halogeton invasion.
3. In burned plots with small mammals excluded, SEEDLING survival was much higher (61%) than in non-exclusion plots (9%).

41. Do you consider Kangaroo rats a nuisance species post-wildfire? (*N* = 196, 77%)

No	Sometimes	Neutral	Always	I don't know
19%	18%	26%	6%	32%

This question was for gauging general nuisance of this species. Associations thus aren’t needed or particularly interesting.

42. Given these results, if Kangaroo rat density is high, would you increase your seeding density? (*N* = 171, 67%)

Absolutely	If we had the money	If we had the time	If we had money and time	I don't think it matters
13%	46%	4%	9%	27%

	Increasing seed. dm = doesn't matter	Chi.Sq.	DF	p-value
Boruta	> 10 year post-fire tenure	30.641	12	0.002
Boruta	State = CA/ID (AZ/CA dm)	33.385	20	0.031
Boruta	IG science doesn't fit	19.527	8	0.012
Boruta	Locals don't agree with decisions	20.659	12	0.056
Boruta	Fertile islands split (dm, dm)	49.515	20	0
Boruta	Pollinator-based seed	65.308	20	0
Boruta	Exclude kangaroo rats	75.799	16	0
Boruta	Exclude small mammals	59.679	28	0
	Type = Fire manager dm	5.7	4	0.2227
	Monthly state/NP recreation	23	16	0.1216
	Policy doesn't fit	7	8	0.5622
	BSC vs veg split	11	12	0.5037
	Fewer years since fire = opinion	20	16	0.2225
	Gender, Male opinion, female barriers	9.33	4	0.053
	Funding changes proposal	19.851	8	0.011
	Projects crucial/heal split	16.53	8	0.035
	Prefer native species	10.259	4	0.036
	Longer-term spending	12.758	4	0.013
	Locals are not concern (dm neutral)	24.716	12	0.016
	Drought/floods concerned, 0 no concern	21.732	12	0.041
	Temperatures concerned, 0 no concern	22.127	12	0.036
	Not concerned halogeton (dm same)	19.915	12	0.069

43. Would you apply for funding to exclude or control Kangaroo rat density? (*N* = 164, 64%)

Absolutely	If we had the money	If we had the time	If we had money and time	I don't think it matters
9%	24%	6%	13%	48%

	Absolutely exclude (dm = doesn't matter)	Chi.Sq.	DF	p-value
Boruta	6-10 y postfire tenure (dm less with years)	19.789	12	0.071

Boruta	IG crucial (dm same)	21.215	8	0.007
Boruta	Pollinator based seed	35.75	20	0.016
Boruta	Kangaroo rats are a nuisance	27.278	16	0.038
Boruta	Increase seed when kangaroo rats	75.799	16	0
Boruta	Halogeton is a concern	43.484	12	0
Boruta	Small mammals response (exclude)*	72.285	28	0
Boruta	Region split (SGB dm)	4.2	8	0.8353
Boruta	State, CA/UT (ID/NV dm)	26	20	0.1778
Boruta	Field (dm field and office)	12	8	0.1338
Boruta	Public precise	3.8	8	0.8757
Boruta	Support experiments	15	12	0.2485
Boruta	Drought/floods are a concern (dm same)	14	12	0.333
	Type	9.699	4	0.046
	Halogeton control	22.87	12	0.029
	Adapt halogeton herbicide	26.518	12	0.009

44. Halogeton concern was asked to gauge region-wide manager concern about this species presence.

	Disagree	Neutral	Agree	Don't Know
1. I am concerned about Halogeton post-wildfire (*N* = 187, 73%)	12%	21%	42%	25%
2. I typically request money for Halogeton control post-wildfire (*N* = 187, 73%)	32%	29%	7%	32%
3. If small mammal abundance is high, I would request less money for Halogeton herbicide treatments (*N* = 186, 73%)	15%	32%	15%	38%

	Control Halogeton	Chi.Sq.	DF	p-value
Boruta	Region = GB (SGB no)	15.476	6	0.017
Boruta	IG policy doesn’t fit	12.497	6	0.052
Boruta	Public precise policy split	12.03	6	0.061
Boruta	Science doesn’t fit	12.616	6	0.05
Boruta	Role, data collector DK	18.83	6	0.004
Boruta	Time frame changes proposal	22.026	6	0.001
Boruta	BSC useful	8.749	3	0.033
Boruta	BSC over Veg	39.024	9	0
Boruta	Halogeton concern	176.834	9	0
Boruta	Adapt halogeton herbicide	122.483	9	0
	Time frames insufficient	20.189	9	0.017

	State NV (ID,UT no)	26.929	15	0.029
	Funding changes proposal	20.201	6	0.003
	Policy precise	15.885	6	0.014
	Prefer natives	7.287	3	0.063
	Locals are not concerned projects	17.009	9	0.049
	Policy realistic	20.391	9	0.016
	Support experiments	14.921	9	0.093
	Fertile islands adapt	24.09	15	0.064
	Pollinator based seed selection	32.25	15	0.006
	Kangaroo rats nuisance split (opinion)	25.488	12	0.013
	Exclude kangaroo rats split (opinion)	22.87	12	0.029

	Adapt halogeton herbicide	Chi.Sq.	DF	p-value
Boruta	Mid-range postfire tenure	20.389	9	0.016
Boruta	Weekly rangelands recreation least adapt	25.409	12	0.013
Boruta	Time frames change proposal	13.05	6	0.042
Boruta	Projects are crucial	10.725	6	0.097
Boruta	Public precise policy	27.706	6	0
Boruta	Policy unrealistic	19.4	9	0.022
Boruta	Kangaroo rats are a nuisance	54.836	12	0
Boruta	Halogeton concern	124.562	9	0
Boruta	Halogeton control	122.483	9	0
Boruta	Small mammals response (all, any)	31.384	21	0.068
Boruta	Education, some college/graduate degree	14	9	0.1375
Boruta	State CA (NV no, AZ DK)	20	15	0.1538
Boruta	Public science based	9.972	6	0.126
	Mid regional residency	18.979	9	0.025
	Mid-regional tenure	16.335	9	0.06
	Region	11.364	6	0.078
	Risk_fire_10mi_5y	15.914	9	0.069
	Policy precise	16.973	6	0.009
	IG policy doesn’t fit	10.937	6	0.09
	Prioritize best tool	7.148	3	0.067
	Local concerned/neutral	19.972	9	0.018
	IG concerned projects	16.549	9	0.056
	BSC over Veg	21.044	9	0.012
	Pollinator-based seed selection	31.797	15	0.007
	Exclude kangaroo rats	26.518	12	0.009

45. If small mammal density is high, I would request money to (Check all that apply) (N = 167, 65%).

<table>
<tr><th>Increase seeding density</th><th>Change the timing of seeding</th><th>Exclude small mammals</th><th>I would consider none of these options (I don't think it matters)</th><th>Other (please specify)</th></tr>
<tr><td>26%</td><td>10%</td><td>6%</td><td>24%</td><td>8%</td></tr>
<tr><td colspan="2">|--13%--|</td><td>|--1%--|</td><td></td><td></td></tr>
<tr><td colspan="3">|-------| 3% |------|</td><td></td><td></td></tr>
<tr><td colspan="3">|-----------------5%----------------------|</td><td></td><td></td></tr>
</table>

Increase seeding density is the most popular choice in all categories unless noted

	Increase seeding (dm = doesn't matter)	Chi.Sq.	DF	p-value
Boruta	Kangaroo rats not a nuisance (/dk, neutral)	55.958	28	0.001
Boruta	Increase seed when kangaroo rats dm	59.679	28	0
Boruta	Exclude kangaroo rats dm *	72.285	28	0
Boruta	Some college/college degree	26	21	0.2261
Boruta	Lived in community > 10 years	29	21	0.1215
Boruta	> 1 mile to fire risk	22	21	0.4153
Boruta	Vegetation over BSC	23	21	0.3155
Boruta	Pollinator-based seed selection dm	24	21	0.2765
Boruta	Halogeton concern	34	35	0.5136
	Adapt Halogeton herbicide	31.384	21	0.068
	Fire likely	37.267	21	0.016
	Policy doesn't fit, change timing	23.581	14	0.051
	Visibility, only chose seed timing	15.307	7	0.032

Page 12 : Thank You!

Your responses will help us better understand the context of our current research as well as guide our future research. Thank you for participating in this survey!

APPENDIX C

POST-WILDFIRE PUBLIC SURVEY

Post-fire Landscape Response

Department of Environment and Society
5215 Old Main Hill
Logan UT 84322-5215
Telephone: (435) 797-1790

Post-fire Landscape Response

Wildfires threaten both homes and the rangelands that many of us depend on. We need your responses! Your answers can help agencies understand if their actions after a wildfire is what you, the taxpayers and the homeowners at the greatest risk, agree with. Your local knowledge of your community and landscape is crucial to agency action and policies.

Demographics

1. *Age : (N = 149, 98% response rate)*

18-25	26-40	41-60	> 60
14%		32%	54%

2. *Gender: (N = 142, 93% response rate)*

Male	Female
71%	29%

3. *Current residence: (N = 145, 95% response rate)*

Small town or rural area	Large town or urban area
74%	26%

4. *Raised primarily in: (N = 144, 95% response rate)*

Small town or rural area	Large town or urban area
66%	34%

5. *Current property size: (N = 144, 95% response rate)*

< 1 acre	1-10 acres	> 10 acres
63%	27%	10%

6. *Property ownership: (N = 149, 98% response rate)*

Own	Rent
90%	10%

7. *How long have you lived in your community (years)? (N = 149, 98% response rate)*

< 5	5-10	11-15	> 15
13%	17%	13%	56%

8. *How long have you lived in the Mojave Desert and/or Great Basin (years)? (N = 134, 88%)*

< 5	5-10	11-15	> 15
11%	11%	11%	66%

9. *What is your highest level of education? (N = 148, 97% response rate)*

High school	2-year college	4-year college	Graduate degree
30%	26%	26%	18%

10. *What is your current profession? (N = 136, 89% response rate)*

Related profession	Unrelated	Unknown
10%	50%	40%

11. *Do you participate in any of the following activities (Check all that apply)?*

	Never	Rarely	Yearly	Monthly	Weekly
OHV, *N* = 136, 89%	40%	20%	15%	16%	9%
Hiking, *N* = 138, 91%	13%	31%	25%	16%	14%
Camping, *N* = 140, 92%	14%	20%	51%	13%	1%
Backpacking, *N* = 130, 86%	45%	30%	21%	3%	1%
Horse Riding, *N* = 134, 88%	57%	24%	10%	4%	4%
Hunting, *N* = 144, 95%	51%	19%	22%	6%	1%
Fishing, *N* = 146, 96%	25%	24%	28%	18%	5%

Wildfire and Area Usage

12. *About how far is it from your house to an area where a wildfire might burn (miles)?* (N = 141, 93%)

< 1 mile	1-5 miles	6-10 miles	> 10 miles
42%	38%	8%	12%

13. *If any wildfires have burned close to your home, how many miles away was the fire from your property (miles)?* (N = 120, 79%)

< 1 mile	1-5 miles	6-10 miles	> 10 miles	NA
16%	41%	15%	28%	25%

b. *How long ago was that fire (years)?* (N = 121, 80%)

< 5 years	5-10 years	11-20 years	> 20 years
64%	28%	4%	3%

14. *What is the likelihood that a wildfire could occur < 10 miles from your house in the next 5 years?* (N = 149, 98%)

Unlikely	Likely	Very Likely	Don't Know
21%	34%	38%	7%

15. *About how often do you spend time on multiple-use rangelands?* (N = 147, 97%)

Never	Rarely	Yearly	Monthly	Weekly
20%	23%	19%	28%	10%

16. *About how often do you spend time in state or national parks?* (N = 149, 98%)

Never	Rarely	Yearly	Monthly	Weekly
2%	28%	52%	13%	5%

Agency and Policy effectiveness

We're interested in Mojave Desert and Great Basin resident opinions about post-wildfire agency projects.

17. *Choose the opinion you agree with most:* (*N* = 139, 91%)

67%	Post-wildfire projects are crucial to site rehabilitation
31%	The ecosystem will naturally heal itself
1%	DK and NA

Boruta confirmed the following attribute importance (* = significant): Drought/floods concern/not*, Reseeding is effective/not*, Severity vs visibility; and tentative attributes: Future wildfire is likely/not, Concerned/not about fire risk to human safety*, and Concerned/not about erosion.

Analysis of these variables (see extensive tables below survey) suggest project importance was unlikely to be driven by demographic variables, and more likely to be driven by ecological and personal risk concerns (e.g. wildfire risk, human safety risk, droughts/floods). Invasive grass and forb concern, although not identified in Boruta, were significant predictors of project importance. Agency trust and social opinion did not have an impact on project importance upon closer inspection of variables (removal of DK's, etc.).

18. *Choose the opinion you agree with most:* (*N* = 135, 89%)

10%	Post-wildfire projects should strive to follow agency policy precisely
89%	Post-wildfire agency policy does not always fit specific situations in my area
1%	DK

Boruta identified the following attributes: Concern about invasive forbs, Invasive forbs fire-related concern, Invasive grasses fire-related concern*, Safe driving fire-related concern*, Science realistic/not*, Severity vs visibility*, Support experiments/not*; and tentative attributes: Drill vs aerial, Trust/don't agencies

Analysis of these variables (see extensive tables below survey) suggested overall that precise policy was often preferred by respondents at less wildfire and wildfire associated concerns risk (see extensive tables below survey). Also those with no trust in agencies and that prefer visibility of course.

19. *Choose the opinion you agree with most:* (*N* = 138, 91%)

41%	Project choices should be based on scientific research
58%	Science often doesn't reflect the reality on the ground
1%	DK

Boruta identified the following attributes: Education*, Years since nearby wildfire, Reseeding is effective/not*, Fire-related risk to human safety*, Seedcover effective/not*, Support experiments/not*, Distance to previous wildfire*, Severity vs visibility.

Analysis of these variables (see extensive tables below survey), seems to suggest similar to policy realism, wildfire risk and associated concerns with personal safety are important predictors of science validity. Those with higher degrees were more likely to trust science. Those that felt reseeding and seedcover are not effective, and do not support experiments, are unlikely to support science.

20. *Choose the project you believe should receive higher priority:* (*N* = 139, 91%)

7%	Locations where the public will see treatments on a regular basis
91%	Locations where the post-wildfire ecosystem effect is the most severe
2%	DK and NA

Boruta identified the following attributes: Erosion fire-related concern/, Habitat fire-related concern*, Invasive forbs fire-related concern*, Invasive grasses fire-related concern*, Prefer native vs accept non-native species*, Water supply fire-related concern/, General policy realistic/not*, Trust/don’t agencies/, Concerned about projects prior to this survey*, Forage fire-related concern*

N is probably too low for robust statistical analysis. The 7% of public that preferred sites to be visible tended to also have a lack of concern about erosion, habitat, forage, water supply, invasive grasses, and invasive forbs; they also tended to prefer non-native species; but this can’t be said with certainty.

21. *Choose the project you believe should receive the higher priority:* (*N* = 141, 93%)

66%	A site with high invasion of cheatgrass or red brome (increased fire risk)
33%	A site with lower invasion of cheatgrass or red brome, but more domestic livestock
1%	DK

Boruta identified the following attributes: Invasive grasses concern, Preferred seed mix, and Invasive grasses fire-related concern.

Analysis of these variables (see extensive tables below survey) indicate no demographic variables predict livestock prioritization. Those not concerned about grasses and forbs were more likely to prioritize livestock. Trust in agencies and policy, more likely to prioritize annual grasses. While those closest to recent wildfires prioritized livestock, those that felt themselves the most at risk to future wildfire were least likely to prioritize livestock.

22. *Choose the project you believe should receive the higher priority:* (*N* = 141, 93%)

62%	Reseeding with natives, even if it costs more
38%	Reseeding with the species most likely to establish, even if non-native
1%	DK

Boruta identified the following attributes: Aesthetic fire-related concern/, Erosion fire-related concern, Preferred seed mix, Seedcover effective/not/, Severity vs. visibility, and Property size.

Analysis of these variables in conjunction with all those found significant (see extensive tables below survey) identified the following division of predicting variables: 2 coarse scale social-political (e.g. trust agencies), 3 fine-scale social-political (e.g. smaller properties), 3 wildfire risk (e.g. more recent since wildfire), 0 place exposure, 6 coarse-scale ecological (e.g. projects are effective, science is realistic, drought/flood concern), and 9 fine-scale ecological variables (e.g. concern about invasive plants, prioritize severity over livestock, less concerned about erosion)

Overall, those nearest to the land and with larger properties were more likely to accept non-natives, however those with greater wildfire risk preferred native species. Those concerned about erosion, aesthetic, visibility, human safety, and livestock were more likely to prefer non-natives (notably, livestock was actually split 51/49%). Those concerned about droughts/floods, invasive grass and forbs, water supply, and severity over visibility were more likely to prefer natives and were more likely to trust agencies.

23. *There is very little public concern about post-wildfire projects:* (*N* = 146, 96%)

Disagree	Neutral	Agree	Don't Know
25%	17%	46%	12%

Boruta identified the following attributes: Hunting*, Profession2*, Raised in urban or rural community*, Drill vs aerial*, Larger public is concerned/not about projects*, Local citizens agree/don’t with decisions*, Recreation/, Concerned about projects prior to this survey*, Fishing/, Horse Riding/, Property size/, Concern about invasive forbs*, Precise policy/no*.

Analysis of these variables (see extensive tables below survey) suggest respondents that felt locals are concerned about projects were more likely to be: hunters, raised in rural communities, live on larger properties, own those properties, > 40 years old, closer to wildfire, more wildfire risk, feel locals don't agree with decisions, that policy is realistic, projects are crucial, support experiments, invasive grass and forb concern, droughts/floods concern, neutral/not concerned about temperatures, agencies are effective. This seems to suggest overall that local concern is driven by support of agencies, but concern that projects are not as effective as they could be.

24. *While the larger public is not concerned about post-wildfire projects, the local community is concerned:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
8%	15%	64%	12%

Boruta identified the following attributes: Raised in rural or urban community*, Live in rural or urban community*, Concerned about encroachment*.

Analysis of these variables (see extensive tables below survey) suggest when citizen respondents' think larger public does care, they were more likely to: live in rural communities (urban more likely neutral), live in the Mojave Desert, be female, own property, don't care about visibility, policy is realistic, not as concerned about encroachment, drought/floods and temperatures *opinion*, habitat fire-related concern, don't know if seedcover is effective. Even when the local public is concerned, same perception of larger public lack of concern. Those neutral about larger public concern were more likely to: prefer visible sites, prefer annual grasses over livestock (livestock more likely DK), think locals are not concerned, trust agencies, believe locals agree with decisions.

25. *Before this survey I was concerned about post-wildfire projects:* (*N* = 144, 95%)

Disagree	Neutral	Agree	Don't Know
15%	28%	51%	5%

Boruta identified the following attributes: Backpacking*, Horse Riding*, Hunting*, State/NP recreation*, Property size/ and Rangelands recreation*, Concerned about encroachment*,Concern about invasive forbs*, Drill vs aerial*, Precise policy/no*, Public concerned/not*, Support experiments/not*, Severity vs visibility*, Agencies effective at stabilizing soils/not*, Invasive grasses concern*.

Analysis of these variables (see extensive tables below survey) suggest concern was associated with more frequent backpacking, horse riding, hunting, state/np recreation, and range recreation. Public with larger property sizes were more likely to be concerned, though this was not significant. Prior concern was most predicted by specific ecological concerns (invasive grasses and forbs, encroachment). Those that identified themselves as concerned before the survey, were more likely to think local public also care, policy is realistic, drills are better than aerial seeding, and agencies are effective.

26. *The local community agrees with the majority of post-wildfire treatments:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
8%	33%	30%	29%

Boruta identified the following attributes: Years lived in community/, OHV*, Profession2*, Property size*, Aesthetic/, Drill vs aerial*, Safe driving fire-related concern*, Temperatures*, Trust/don't agencies*.

Analysis of these variables (see extensive tables below survey) suggest local agreement of decisions was highest among those who have lived in the community the shortest and longest times (>15 years representing the better ones to approach for innovation; however those with larger property sizes were more likely to disagree. Opinion that locals agree with decisions was more likely for those with a related profession and those who OHV the most frequently. Concern about safe driving was an important predictor of local agreement while *not* being concerned about aesthetic was also important. If respondents trusted agencies, they were more likely to think locals agree with decisions.

27. *Official agency policy is sometimes opposed to what makes sense on the landscape:* (*N* = 146, 96%)

Disagree	Neutral	Agree	Don't Know
7%	20%	58%	15%

Boruta identified the following attributes: Concerned about encroachment, Forage, Public concerned/not, Concerned about projects prior to this survey, Trust/don't agencies, Backpacking, and Larger public is concerned/not about projects.

Analysis of these variables (see extensive tables below survey) suggest respondents' that think policy is realistic were more likely to backpack frequently, were less concerned about wildfire risks, were unlikely to prioritize livestock, were unlikely to be concerned about encroachment, were less concerned about forage, thought larger public is not concerned (less outside influence), were concerned about projects prior to this survey, and trust agencies.

28. *I trust agencies to respond appropriately post-wildfire:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
19%	18%	57%	6%

Boruta identified the following attributes: Own vs rent/, Concerned about encroachment*, Local citizens agree/don't with decisions*, Precise policy/no*, State/NP recreation*, and Residence*.

Analysis of these variables (see extensive tables below survey) suggest trust was higher for respondents' living in urban communities and renting, and trust increased with more frequent NP recreation (decreased though not significant with most frequent range recreation). Those concerned about encroachment trusted agencies, and of course when locals agree with decisions, and policy is realistic respondents' were more likely to trust agencies to respond effectively. Respondents' were less likely to trust agencies if they prioritized livestock, if they think temperatures are not a risk, and droughts/floods are not changing.

29. *I support experimental post-wildfire treatments that science suggest may work, but haven't been directly tested yet:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
16%	17%	59%	8%

Boruta identified the following attributes: 0 wildfire risk, 0 coarse-scale social political, 5 fine-scale social-political (Local citizens agree/don't with decisions, Concerned about projects prior to this survey, and 3 of which are place exposure Backpacking = opinion*, OHV = opinion/, Camping = opinion/), 3 coarse-scale ecology (Reseeding is effective/not, Science realistic/not, Seedcover effective/not), and 1 fine-scale ecology (concerned about water supply/). Additional Chi-squared analysis identified the following significant variables (see table below): 3 coarse-scale social-political (Policy precise/not, General policy realistic/not, Trust/don't agencies) 6 fine-scale (Gender, Public is concerned/not about post-wildfire projects, larger public is concerned/not about post-wildfire projects, recreation concern) + 0 future wildfire risk + 2 exposure (Fishing, NP recreation), 5 coarse-scale ecology (Projects are crucial/naturally heal, Prefer native vs accept non-natives, Agencies effective at stabilizing soils/not, Drought/flood, Temperatures), 7 fine-scale ecology (Severity vs visibility, Prioritize annual grass vs livestock, concerned about encroachment, Concern about invasive forbs, Invasive grasses concern, habitat, Preferred seed mix)

Analysis of these variables are discussed in depth in Chapter 3.

Support experiments	Chi-squared	Df	p-value
Men more likely to disagree than women, women more likely dk	15.604	3	0.001
Backpacking = opinion*	19.959	12	0.068
Fishing = opinion	19.896	12	0.069
State/NP recreation	20.317	12	0.061
Projects are crucial/naturally heal	20.465	6	0.002

General policy realistic/not	23.851	6	0.001
Science based projects*	34.881	6	0
Severity vs visibility	19.603	6	0.003
Prioritize annual grass vs livestock	17.305	6	0.008
Prefer native vs accept non-natives	15.798	6	0.015
Public concerned/not	25.599	9	0.002
Larger public is concerned/not about projects	26.532	9	0.002
Precise policy/no	22.035	9	0.009
Split, p driven by neutral prior concern*	35.585	9	0
Trust/don't agencies	30.032	9	0
Agencies effective at stabilizing soils/not	19.624	9	0.02
Concerned about encroachment	15.701	9	0.073
Concern about invasive forbs	26.153	9	0.002
Invasive grasses concern	44.67	9	0
Drought/flood events are a risk	50.121	9	0
Habitat	18.141	9	0.034
Locals agree with most decisions*	39.029	9	0
Preferred seed mix	48.467	36	0.08
Recreation concern	26.964	9	0.001
Reseeding is effective*	44.308	9	0
Seedcover is effective*	39.087	9	0
Temperature shifts are a danger	33.825	9	0

30. *Ecosystems near where I live and/or work are in danger due to drought and/or flood potential:* (N = 144, 95%)

Disagree	Neutral	Agree	Don't Know
9%	7%	74%	10%

Boruta identified the following attributes: OHV recreation*, Profession related/not*, Property size/, Erosion fire-related concern*, Projects are crucial/naturally heal*, Fire-related risk to human safety*, Smoke fire-related concern/, Temperatures concern*.
3 coarse-scale social-political (e.g. trust agencies), 17 fine-scale social-political (e.g. local opinions, own or rent), of which 2 future wildfire risk (e.g. wildfire likely) and 5 place exposure (e.g. OHV more frequently, years lived in region), 8 coarse-scale ecological variables (e.g. temperature changes, reseeding is effective), and 7 fine-scale ecological variables (e.g. erosion concern, severity vs livestock preference).

Analysis of these variables (see extensive tables below survey) suggest those that OHV the most frequently were more likely to be concerned about drought/flood risks. Fire-related concerns about erosion, human safety, and smoke were related to droughts/floods change concerns, in addition to concern about temperature change risks. Those neutral about temperatures were also more likely to be concerned about droughts/floods. Respondents' experiencing past fire closer to their homes (< 5 miles) were more likely to have an opinion, while those who perceived greater future wildfire risk were more likely to be definitively concerned about drought/flood risks.

31. *Ecosystems near where I live and/or work are in danger due to changes in local temperatures:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
25%	19%	43%	14%

Boruta identified the following attributes: Years lived in community, Hunting, Drill vs aerial, Drought/floods, Local citizens agree/don't with decisions, Public concerned/not, and Smoke fire-related concern.

3 coarse-scale social-political (e.g. trust agencies, policy realistic), 7 fine-scale social-political (e.g. local opinions, specific concerns such as smoke), of which 1 wildfire risk (future wildfire likely) and 4 place exposure (lived in community longest, more frequent hunting and fishing), 5 coarse-scale ecological (e.g. dought/flood concerns, science is realistic), and 4 fine-scale ecological (invasive species concerns – none related to research, Chapter 4).

Analysis of these variables (see extensive tables below survey) suggest, respondents' that engaged in more frequent hunting, although not significant seemed to exhibit more temperature concern and vice versa. Additionally, those who had lived in the community the longest were more likely to think temperature are changing (from 25% shortest community tenure to 52% longest tenure, compared to 30 and 23% disagree). As is likely evident from these numbers, neutrality also decreased with tenure, where as those who have lived in the area the shortest amount of time were more uncertain about temperature change. Those that seemed to be more aware of restoration activities (re: answered drill vs aerial) and those concerned about smoke were more likely to agree temperatures are changing. However, those that felt local citizens are concerned about projects and those with a livestock priority were more likely to think temperatures are *not* changing. Those neutral about local agreement were more likely to think temperatures are not changing and those that felt locals don't agree with management decisions were > 2x more likely to be neutral about temperatures than those that felt locals do agree with management decisions.

32. *I am concerned about invasive/weedy grasses on public lands:* (*N* = 144, 95%)

Disagree	Neutral	Agree	Don't Know
9%	12%	74%	6%

Boruta identified the following attributes: Future wildfire likelihood, Region/, Concern about invasive forbs*, Invasive forbs fire-related concern*, Invasive grasses fire-related concern*, and Recreation/.

Analysis of these variables (see extensive tables below survey) suggest invasive grasses were more of a perceived concern for Great Basin residents, those that felt at the greatest risk of wildfire, and those concerned about wildfire effects on recreation opportunities. Additionally, while concern about forbs was unsurprisingly related to concern about grasses, public were more likely to be concerned about grasses than forbs. Livestock prioritization and lack of trust in agencies were both significantly related to less concern about invasive grasses.

33. *I am concerned about invasive/weedy wildflowers on public lands:* (*N* = 145, 95%)

Disagree	Neutral	Agree	Don't Know
15%	21%	57%	6%

Boruta identified the following attributes: Invasive grasses concern, Invasive forbs fire-related concern, Invasive grasses fire-related concern, General policy realistic/not, Concerned about projects prior to this survey.

Analysis of these variables (see extensive tables below survey) suggest respondents' in the Great Basin were more likely to be concerned about invasive forbs than those in the Mojave Desert. While concern about grasses was unsurprisingly related to invasive forb concern, again, those not concerned about invasive grasses were highly unlikely to be concerned about invasive forbs. Those concerned before the survey were more likely to be concerned about invasive forbs.

34. *I am concerned about tree encroachment on public lands:* (*N* = 146, 96%)

Disagree	Neutral	Agree	Don't Know
46%	23%	25%	6%

Boruta identified the following attributes: Age/, Hunting*, Raised*, Rangelands recreation*, Larger public is concerned/not about projects*, Profession/, Concern about invasive forbs*, and Reseeding is effective/not*.

Analysis of these variables (see extensive tables below survey) suggest concern about encroachment was primarily driven by hunting and range recreation frequency, and was more likely for those raised in rural communities. When respondents felt outside public are concerned about projects, they themselves were less likely to be concerned about encroachment. Encroachment was the least concern compared to invasive grasses and forbs - not concerned about forbs, not concerned about encroachment; but neutrality uncertainty about forbs were much more likely to not be concerned about encroachment. If reseeding is considered an effective strategy, public were more likely to be concerned about encroachment.

35. *Which of the following possible reseeding mixes is the most preferable to you post-wildfire: Check all that apply.* (*N* = 148, 97%)

	All native spp	Benefit wildlife	Benefit livestock	Climate resilient	No reseeding	Don't Know
Only answer	30%	22%	9%	11%	1%	12%
In answer	38%	33%	19%	18%	2%	

Boruta identified the following attributes: Distance to wildfire risk area, frequency of state/np recreation, Profession, Native vs non-native species, Public concerned/not, Severity vs livestock, Forage fire-related concern.

Analysis of these variables suggested very few respondents' respondents generally preferred seed mixes to be all native species and to benefit wildlife. Those with more wildfire risk were most likely to prefer native species, while those further away were more likely to prefer climate and wildlife. Public concern = natives, livestock = wildlife (none chose climate), forage = natives and wildlife, natives = natives, related profession = wildlife and livestock, NP recreation = natives, wildlife, climate (not livestock).

36. *Please indicate how concerned you are about the following possible effects from a wildfire:*

	Very concerned	Slightly concerned	Neutral	Not concerned
Risk to human safety/health (*N* = 148, 97%)	64%	27%	5%	4%
Increased levels of smoke (*N* = 147, 97%)	45%	39%	7%	9%
Hazard to safe driving (*N* = 145, 95%)	28%	40%	13%	19%
Deteriorated public water supply (*N* = 145, 95%)	56%	27%	10%	8%
Increased soil erosion (*N* = 147, 97%)	57%	33%	7%	3%
Loss of forage (*N* = 147, 97%)	54%	39%	5%	2%
Loss of wildlife and fish habitat (*N* = 147, 97%)	67%	26%	6%	1%
Increase in invasive grasses	45%	38%	14%	3%

(*N* = 146, 96%)				
Increase in invasive wildflowers (*N* = 143, 94%)	34%	41%	17%	8%
Effects on recreation activities (*N* = 145, 95%)	26%	42%	19%	13%
Reduced scenic quality (*N* = 145, 95%)	35%	38%	18%	9%

Risk human safety: Boruta identified the following attributes: Backpacking*, Residence*, Erosion fire-related concern*, Safe driving fire-related concern*, Seedcover effective/not*, and Smoke fire-related concern/

Smoke: Boruta identified the following attributes: Distance to previous wildfire/, Hunting*, OHV*, Aesthetic fire-related concern*, Forage fire-related concern*, Habitat fire-related concern*, Invasive grasses fire-related concern*, Fire-related risk to human safety*, Safe driving fire-related concern*, Severity vs visibility*, and Erosion* and fire-related concern.

Driving: Boruta identified the following attributes: Fishing*, Years since nearby wildfire/. Aesthetic fire-related concern *, Forage fire-related concern*, Invasive grasses fire-related concern*, Recreation fire-related concern*, Fire-related risk to human safety*, Smoke fire-related concern*, Water supply fire-related concern*. fire-related concern Erosion*, Local citizens agree/don't with decisions, and Education*

Water supply: Boruta identified the following attributes: Backpacking/, Profession/, Raised in urban or rural communities/, Years since nearby wildfire/. Erosion fire-related concern *, Habitat fire-related concern*, Invasive forbs fire-related concern*, Invasive grasses fire-related concern*, Local citizens agree/don't with decisions*, Recreation fire-related concern*, Trust agencies*, Support experiments/not/, Fire-related risk to human safety*, Safe driving fire-related concern*, Public concerned/not*, Rangelands recreation/.

Erosion: Boruta identified the following attributes: Years lived in community/. Aesthetic fire-related concern*, Forage fire-related concern*, Habitat fire-related concern*, Projects are crucial/naturally heal/, Invasive forbs fire-related concern*, Fire-related risk to human safety*, Water supply fire-related concern*, Invasive grasses fire-related concern*), Recreation fire-related concern*

Forage: Boruta identified the following attributes: Education/, Fishing/, Hunting/, Raised/, Rangelands recreation/, Agencies effective at stabilizing soils/not/,Concerned about encroachment, Erosion fire-related concern, Habitat fire-related concern, Invasive forbs fire-related concern, Invasive grasses fire-related concern, Recreation fire-related concern, Preferred seed mix, Precise policy/no/, Fire-related risk to human safety.

Habitat: Boruta identified the following attributes: Erosion fire-related concern*, Forage fire-related concern*, Invasive forbs fire-related concern*, Invasive grasses fire-related concern*, Recreation fire-related concern*, Severity vs visibility*, Reseeding effective/, Water supply fire-related concern*

Invasive grasses: Boruta identified the following attributes: Aesthetic fire-related concern*, Concern about invasive forbs*, Invasive grasses concern*, Erosion fire-related concern*, Forage fire-related concern*, Habitat fire-related concern*, Severity vs visibility*,Water supply fire-related concern*, Invasive forbs fire-related concern*,Preferred seed mix, Safe driving fire-related concern*, Smoke fire-related concern*, Support experiments/not/, Years lived in region/

Invasive forbs: Boruta identified the following attributes: Fishing/, Distance to previous wildfire/, Raised in urban or rural community*, Concern about invasive forbs*, Invasive grasses concern*, Erosion fire-related concern*, Forage fire-related concern*, Habitat fire-related concern*, Water supply fire-related concern*, Invasive grasses fire-related concern*, Recreation fire-related concern*, Preferred seed mix/, Concerned about projects prior to this survey*

Recreation: Boruta identified the following attributes: Backpacking/, Fishing/, Profession/. Precise policy/no/, Fire-related risk to human safety*, Safe driving fire-related concern*, Water supply fire-related concern*, Erosion fire-related concern*, Forage fire-related concern*, Invasive forbs fire-related concern*, Aesthetic fire-related concern*, Habitat fire-related concern*.

Aesthetic: Boruta identified the following attributes: Concerned about projects prior to this survey*, Preferred seed mix/, Smoke fire-related concern*, Safe driving fire-related concern*, Water supply fire-related concern*, Erosion fire-related concern*, Invasive grasses fire-related concern*, Recreation fire-related concern*, Fishing/, Forage fire-related concern *, Habitat fire-related concern*, Fire-related risk to human safety*.

Analysis of these variables (see extensive tables below survey) suggest respondents were most concerned (more than 50%) about wildlife and fish habitat, risk to human safety/health, increased soil erosion, deteriorated public water supply, and loss of forage. They were the least concerned about driving and recreation. Backpacking, fishing, and hunting seem to consistently be some of the most predictive for concerns; typically concern increases with frequency. While respondents were concerned about invasive grasses and forbs, they were not the variables they were most concerned about.

37. *Reseeding is likely an effective means of improving ecosystem health:* (*N* = 150, 99%)

Disagree	Neutral	Agree	Don't Know
4%	13%	77%	6%

Boruta identified the following attributes: Backpacking/, Distance to previous wildfire/, Region*, Rural or urban community/, Habitat fire-related concern*, Projects are crucial/naturally heal*, Science realistic/not*, Seedcover effective/not*, Support experiments/not*. Concerned about encroachment*, Preferred seed mix*

Analysis of these variables (see extensive tables below survey) suggest reseeding was more likely to be considered effective by rural residents, those living in the Great Basin, those further away from previous fire, and those that backpack the most frequently. Those concerned about habitat and encroachment were also more likely to support reseeding (not invasive species). People that felt projects are crucial, science is realistic, seedcover is effective, and support experiments felt reseeding was effective.

38. *Covering seed (via chaining/mechanical/mulch treatments) likely is an effective means to improve project success*: (N = 150, 99%)

Disagree	Neutral	Agree	Don't Know
3%	22%	55%	20%

Boruta identified the following attributes: Hunting/. Science realistic/not*, Precise policy/no*, Support experiments/not*, Fire-related risk to human safety/, Erosion fire-related concern/, Recreation fire-related concern/, Reseeding is effective/not*, Drill vs aerial*, Horse Riding/, Years lived in region/, Region/, Invasive grasses concern*.

Analysis of these variables (see extensive tables below survey) suggest horse riders and those that have lived in the region longer were more likely to think seedcover is effective; hunters and Great Basin residents felt seedcover not effective (Mojave Desert more uncertain). Those concerned about erosion, human safety, recreation, and invasive grasses were the more likely to think seedcover is effective. Those that do not think seedcover is effective were not surprisingly more likely to think science is unrealistic, don't support experiments, and think reseeding and drilling are not effective.

39. *Drill seeding is more effective than aerial seeding*: (N = 150, 99%)

Disagree	Neutral	Agree	Don't Know
3%	25%	35%	38%

Boruta identified the following attributes: Agencies effective at stabilizing soils/not*, Local citizens agree/don't with decisions*, Seedcover effective/not*, Concerned about projects prior to this survey*, Temperatures*, Concerned about encroachment*, Years lived in community/, State/NP recreation/, and Property size*.

Analysis of these variables (see extensive tables below survey) suggest those that recreate most in state/NP don't like drill seeding, while longer residency and larger property sizes were more likely to have an opinion. If locals don't agree with decisions and if respondents' were interested in projects before the survey, they were more likely to have an opinion. If agencies are ineffective, most likely to be neutral about drill. When respondents' think seedcover is effective and they were concerned or had no opinion regarding temperatures, they more likely to prefer drilling.

40. *Agencies effectively stabilize erosion and reduce flooding concerns:* (*N* = 150, 99%)

Disagree	Neutral	Agree	Don't Know and NA
17%	24%	37%	21% and 1%

Boruta identified the following attributes: Education/, OHV*, Region/, Drill vs aerial, Recreation, Water supply fire-related concern, Invasive grasses fire-related concern, Local agreement/no.

Analysis of these variables (see extensive tables below survey) suggest respondents' with highest degrees were more likely to think agencies are *not* effective, while the least educated were more likely to think agencies are effective. Those in the Mojave Desert more likely to think effective, while Great Basin respondents tended to be more neutral. More frequent recreation, and more OHV = more effective, but more concern about effects of fire on recreation decreased effectiveness. Not concerned about water supply, agencies were ineffective; concern about grasses, agencies effective. When respondents' felt locals agree with most management decisions, they were more likely to think agencies effective

41. ***Please tell us about any other concerns you may have that were not covered in this survey and relate to post-wildfire management:***

Public respondents also commented that they don't feel agencies effectively thin/graze areas to prevent wildfire and pine beetles. Some had road closure and access concerns. Some felt public education, awareness, communication, and even fines are needed.

The most frequent comment was related to more public involvement and communication (8 responses). Reducing fine fuel loads (6), natural fire cycles (5), anger/distrust of agencies (5), and grazing support/concerns (4) were also voiced.

Thank you for participating in our survey!

Your help is greatly appreciated!

For the following tables, see the corresponding question in the public survey.

Table 1

Crucial versus naturally heal

Row	Column	Chi.Sq.	DF	p-value
Crucial/naturally heal	Policy realism	133.046	4	0
Crucial/naturally heal	Science realism	135.133	4	0
Crucial/naturally heal	Severity/visibility	136.71	4	0
Crucial/naturally heal	Prioritize severity/livestock	137.092	4	0
Crucial/naturally heal	Prefer natives/non-natives	137.036	4	0
Crucial/naturally heal	Public concerned/not	18.545	6	0.005
Crucial/naturally heal	Lar. pub. concern/not	12.607	6	0.05
Crucial/naturally heal	Policy precise/not	13.445	6	0.036
Crucial/naturally heal	Prior concerned/not	34.557	6	0
Crucial/naturally heal	Trust agencies/not	21.786	6	0.001
Crucial/naturally heal	Support experiments/don’t	20.465	6	0.002
Crucial/naturally heal	Drought/floods risk	16.554	6	0.011
Crucial/naturally heal	Inv. grass fire concern/not	33.778	6	0
Crucial/naturally heal	Inv. forb fire concern/not	34.949	6	0
Crucial/naturally heal	Human safety/not	25.387	6	0
Crucial/naturally heal	Habitat	13.399	6	0.037
Crucial/naturally heal	Invasive grass concern/not	11.959	6	0.063
Crucial/naturally heal	Reseeding effective/not	40.279	6	0
Camping	Crucial/naturally heal	13.536	8	0.095
House miles to fire risk	Crucial/naturally heal	18.78	6	0.005
Future close wildfire likely	Crucial/naturally heal	15.938	6	0.014

Table 2

Science realism

Row	Column	Chi.Sq.	DF	p-value
Science realism	Severity/visibility	136.022	4	0
Science realism	Prioritize severity/livestock	136.347	4	0
Science realism	Prefer natives/non-natives	137.332	4	0
Science realism	Lar. pub. concern/not	10.88	6	0.092
Science realism	Policy precise/not	19.584	6	0.003
Science realism	Prior concerned/not	27.217	6	0
Science realism	Trust agencies/not	31.679	6	0
Science realism	Support experiments/don’t	34.881	6	0
Science realism	Drought/floods risk	14.258	6	0.027
Science realism	Temperatures	13.732	6	0.033
Science realism	Inv. grass fire concern/not	34.897	6	0
Science realism	Inv. forb fire concern/not	24.348	6	0

Science realism	Human safety/not	23.156	6	0.001
Science realism	Erosion	11.484	6	0.075
Science realism	Reseeding effective/not	30.193	6	0
Science realism	Seedcover effective/not	12.939	6	0.044
Residence	Science realism	6.066	2	0.048
Education	Science realism	22.859	6	0.001
House miles to fire risk	Science realism	16.771	6	0.01
Miles from past fire	Science realism	8.739	3	0.033
Future close wildfire likely	Science realism	15.844	6	0.015
Crucial/naturally heal	Science realism	135.133	4	0
Policy realism	Science realism	137.418	4	0

Table 3
Prioritize severity / visibility

Row	Column	Chi.Sq.	DF	p-value
Severity/visibility	Prioritize severity/livestock	137.028	4	0
Severity/visibility	Prefer natives/non-natives	142.166	4	0
Severity/visibility	Lar. pub. concern/not	15.452	6	0.017
Severity/visibility	Prior concerned/not	30.373	6	0
Severity/visibility	Trust agencies/not	22.586	6	0.001
Severity/visibility	Support experiments/don't	19.603	6	0.003
Severity/visibility	Drought/floods risk	11.712	6	0.069
Severity/visibility	Inv. grass fire concern/not	26.549	6	0
Severity/visibility	Inv. forb fire concern/not	21.378	6	0.002
Severity/visibility	Human safety/not	22.384	6	0.001
Severity/visibility	Forage	12.06	6	0.061
Severity/visibility	Habitat	27.043	6	0
Severity/visibility	Invasive grass concern/not	14.847	6	0.021
Severity/visibility	Invasive forbs concern/not	16.821	6	0.01
Severity/visibility	Reseeding effective/not	17.342	6	0.008
Backpacking	Severity/visibility	15.709	8	0.047
House miles to fire risk	Severity/visibility	13.182	6	0.04
Future close wildfire likely	Severity/visibility	14.722	6	0.023
Rangelands recreation	Severity/visibility	15.467	8	0.051
Frequency state/NP recreation	Severity/visibility	18.732	8	0.016
Crucial/naturally heal	Severity/visibility	136.71	4	0
Policy realism	Severity/visibility	138.302	4	0
Science realism	Severity/visibility	136.022	4	0

Table 4
Prioritize severity/livestock

Row	Column	Chi.Sq.	DF	p-value
Prioritize severity/livestock	Prefer natives/non-natives	142.365	4	0
Prioritize severity/livestock	Lar. pub. concern/not	15.274	6	0.018
Prioritize severity/livestock	Policy precise/not	11.508	6	0.074
Prioritize severity/livestock	Prior concerned/not	25.981	6	0
Prioritize severity/livestock	Trust agencies/not	32.628	6	0
Prioritize severity/livestock	Support experiments/don't	17.305	6	0.008
Prioritize severity/livestock	Drought/floods risk	11.145	6	0.084
Prioritize severity/livestock	Temperatures	14.183	6	0.028
Prioritize severity/livestock	Inv. grass fire concern/not	41.297	6	0
Prioritize severity/livestock	Inv. forb fire concern/not	27.644	6	0
Prioritize severity/livestock	Preferred seed mix	46.588	24	0.004
Prioritize severity/livestock	Human safety/not	17.956	6	0.006
Prioritize severity/livestock	Invasive grass concern/not	22.927	6	0.001
Prioritize severity/livestock	Invasive forbs concern/not	23.256	6	0.001
Prioritize severity/livestock	Reseeding effective/not	20.154	6	0.003
House miles to fire risk	Prioritize severity/livestock	15.053	6	0.02
Miles from past fire	Prioritize severity/livestock	6.317	3	0.097
Future close wildfire likely	Prioritize severity/livestock	15.934	6	0.014
Crucial/naturally heal	Prioritize severity/livestock	137.092	4	0
Policy realism	Prioritize severity/livestock	134.006	4	0
Science realism	Prioritize severity/livestock	136.347	4	0
Severity/visibility	Prioritize severity/livestock	137.028	4	0

Table 5
Prefer natives or non-natives acceptable

Row	Column	Chi.Sq.	DF	p-value
Prefer natives/non-natives	Prior concerned/not	29.305	6	0
Prefer natives/non-natives	Trust agencies/not	26.563	6	0
Prefer natives/non-natives	Support experiments/don't	15.798	6	0.015
Prefer natives/non-natives	Drought/floods risk	14.748	6	0.022
Prefer natives/non-natives	Inv. grass fire concern/not	28.728	6	0
Prefer natives/non-natives	Inv. forb fire concern/not	26.093	6	0
Prefer natives/non-natives	Preferred seed mix	50.21	24	0.001
Prefer natives/non-natives	Human safety/not	18.406	6	0.005
Prefer natives/non-natives	Water supply concern/not	9.715	3	0.021
Prefer natives/non-natives	Invasive grass concern/not	11.247	6	0.081
Prefer natives/non-natives	Invasive forbs concern/not	12.541	6	0.051
Prefer natives/non-natives	Reseeding effective/not	20.815	6	0.002

House miles to fire risk	Prefer natives/non-natives	23.668	6	0.001
Years since nearby wildfire	Prefer natives/non-natives	13.577	6	0.035
Future close wildfire likely	Prefer natives/non-natives	17.07	6	0.009
Crucial/naturally heal	Prefer natives/non-natives	137.036	4	0
Policy realism	Prefer natives/non-natives	134.637	4	0
Science realism	Prefer natives/non-natives	137.332	4	0
Severity/visibility	Prefer natives/non-natives	142.166	4	0
Prioritize severity/livestock	Prefer natives/non-natives	142.365	4	0

Table 6
Public concerned/not

Row	Column	Chi.Sq.	DF	p-value
Public concerned/not	Lar. pub. concern/not	49.879	9	0
Public concerned/not	Policy precise/not	54.921	9	0
Public concerned/not	Prior concerned/not	70.31	9	0
Public concerned/not	Trust agencies/not	26.278	9	0.002
Public concerned/not	Support experiments/don’t	25.599	9	0.002
Public concerned/not	Locals agree /don’t	35.716	9	0
Public concerned/not	Drought/floods risk	27.88	9	0.001
Public concerned/not	Temperatures	20.246	9	0.016
Public concerned/not	Inv. grass fire concern/not	25.921	9	0.002
Public concerned/not	Inv. forb fire concern/not	16.18	9	0.063
Public concerned/not	Preferred seed mix	68.466	39	0.002
Public concerned/not	Water supply concern/not	21.955	9	0.009
Public concerned/not	Reseeding effective/not	16.734	9	0.053
Public concerned/not	Seedcover effective/not	17.058	9	0.048
Public concerned/not	Drilling vs broadcast	26.434	9	0.002
Public concerned/not	Agencies effective/not	17.967	9	0.036
Age	Public concerned/not	11.347	6	0.078
Raised	Public concerned/not	7.687	3	0.053
Own or Rent	Public concerned/not	8.232	3	0.041
Profession2	Public concerned/not	14.803	6	0.022
Hunting	Public concerned/not	23.895	12	0.021
Miles from past fire	Public concerned/not	14.833	9	0.096
Future close wildfire likely	Public concerned/not	19.516	9	0.021
Crucial/naturally heal	Public concerned/not	18.545	6	0.005

Table 7

Larger public is concerned/not

Row	Column	Chi.Sq.	DF	p-value
Lar. pub. concern/not	Policy precise/not	51.914	9	0
Lar. pub. concern/not	Prior concerned/not	28.923	9	0.001
Lar. pub. concern/not	Trust agencies/not	25.421	9	0.003
Lar. pub. concern/not	Support experiments/don’t	26.532	9	0.002
Lar. pub. concern/not	Locals agree /don’t	42.706	9	0
Lar. pub. concern/not	Drought/floods risk	16.397	9	0.059
Lar. pub. concern/not	Temperatures	31.499	9	0
Lar. pub. concern/not	Inv. grass fire concern/not	17.84	9	0.037
Lar. pub. concern/not	Inv. forb fire concern/not	18.614	9	0.029
Lar. pub. concern/not	Encroachment concern/not	31.687	9	0
Lar. pub. concern/not	Habitat	16.278	9	0.061
Lar. pub. concern/not	Reseeding effective/not	38.045	9	0
Lar. pub. concern/not	Seedcover effective/not	24.511	9	0.004
Lar. pub. concern/not	Drilling vs broadcast	15.576	9	0.076
Region	Lar. pub. concern/not	9.319	3	0.025
Gender	Lar. pub. concern/not	10.751	3	0.013
Residence	Lar. pub. concern/not	8.72	3	0.033
Raised	Lar. pub. concern/not	12.034	3	0.007
Own or Rent	Lar. pub. concern/not	10.127	3	0.018
Profession2	Lar. pub. concern/not	15.352	6	0.018
Future close wildfire likely	Lar. pub. concern/not	19.153	9	0.024
Crucial/naturally heal	Lar. pub. concern/not	12.607	6	0.05
Science realism	Lar. pub. concern/not	10.88	6	0.092
Severity/visibility	Lar. pub. concern/not	15.452	6	0.017
Prioritize severity/livestock	Lar. pub. concern/not	15.274	6	0.018
Public concerned/not	Lar. pub. concern/not	49.879	9	0

Table 8

Policy precise/not

Row	Column	Chi.Sq.	DF	p-value
Policy precise/not	Prior concerned/not	46.448	9	0
Policy precise/not	Trust agencies/not	42.862	9	0
Policy precise/not	Support experiments/don’t	22.035	9	0.009
Policy precise/not	Locals agree /don’t	50.866	9	0
Policy precise/not	Drought/floods risk	29.79	9	0
Policy precise/not	Temperatures	28.56	9	0.001
Policy precise/not	Inv. grass fire concern/not	33.411	9	0
Policy precise/not	Inv. forb fire concern/not	39.278	9	0

Policy precise/not	Encroachment concern/not	39.593	9	0
Policy precise/not	Safe driving concern/not	17.835	9	0.037
Policy precise/not	Water supply concern/not	15.467	9	0.079
Policy precise/not	Reseeding effective/not	23.043	9	0.006
Policy precise/not	Seedcover effective/not	17.011	9	0.049
Policy precise/not	Drilling vs broadcast	18.683	9	0.028
Policy precise/not	Agencies effective/not	16.858	9	0.051
Gender	Policy precise/not	11.969	3	0.007
Residence	Policy precise/not	8.573	3	0.036
Own or Rent	Policy precise/not	7.989	3	0.046
Education	Policy precise/not	14.726	9	0.099
Profession2	Policy precise/not	15.325	6	0.018
OHV	Policy precise/not	26.506	12	0.009
Hiking	Policy precise/not	27.727	12	0.006
Backpacking	Policy precise/not	45.25	12	0
Fishing	Policy precise/not	22.667	12	0.031
Future close wildfire likely	Policy precise/not	19.167	9	0.024
Rangelands recreation	Policy precise/not	26.294	12	0.01
Frequency state/NP recreation	Policy precise/not	20.809	12	0.053
Crucial/naturally heal	Policy precise/not	13.445	6	0.036
Policy realism	Policy precise/not	14.786	6	0.022
Science realism	Policy precise/not	19.584	6	0.003
Prioritize severity/livestock	Policy precise/not	11.508	6	0.074
Public concerned/not	Policy precise/not	54.921	9	0
Lar. pub. concern/not	Policy precise/not	51.914	9	0

Table 9
Concerned prior to this survey/not

Row	Column	Chi.Sq.	DF	p-value
Prior concerned/not	Trust agencies/not	52.323	9	0
Prior concerned/not	Support experiments/don’t	35.585	9	0
Prior concerned/not	Locals agree /don’t	29.718	9	0
Prior concerned/not	Drought/floods risk	74.006	9	0
Prior concerned/not	Temperatures	42.057	9	0
Prior concerned/not	Inv. grass fire concern/not	46.81	9	0
Prior concerned/not	Inv. forb fire concern/not	45.131	9	0
Prior concerned/not	Encroachment concern/not	36.467	9	0
Prior concerned/not	Preferred seed mix	53.095	36	0.033
Prior concerned/not	Safe driving concern/not	15.159	9	0.087
Prior concerned/not	Invasive grass concern/not	20.301	9	0.016
Prior concerned/not	Invasive forbs concern/not	15.361	9	0.081

Prior concerned/not	Recreation	19.396	9	0.022
Prior concerned/not	Aesthetic	17.687	9	0.039
Prior concerned/not	Reseeding effective/not	25.245	9	0.003
Prior concerned/not	Seedcover effective/not	15.72	9	0.073
Prior concerned/not	Drilling vs broadcast	28.398	9	0.001
Prior concerned/not	Agencies effective/not	23.867	9	0.005
OHV	Prior concerned/not	19.421	12	0.079
Hiking	Prior concerned/not	20.874	12	0.052
Camping	Prior concerned/not	26.479	12	0.009
Horse Riding	Prior concerned/not	19.469	12	0.078
Hunting	Prior concerned/not	30.492	12	0.002
Fishing	Prior concerned/not	24.253	12	0.019
Miles from past fire	Prior concerned/not	15.115	9	0.088
Future close wildfire likely	Prior concerned/not	33.821	9	0
Rangelands recreation	Prior concerned/not	53.794	12	0
Frequency state/NP recreation	Prior concerned/not	24.372	12	0.018
Crucial/naturally heal	Prior concerned/not	34.557	6	0
Policy realism	Prior concerned/not	33.473	6	0
Science realism	Prior concerned/not	27.217	6	0
Severity/visibility	Prior concerned/not	30.373	6	0
Prioritize severity/livestock	Prior concerned/not	25.981	6	0
Prefer natives/non-natives	Prior concerned/not	29.305	6	0
Public concerned/not	Prior concerned/not	70.31	9	0
Lar. pub. concern/not	Prior concerned/not	28.923	9	0.001
Policy precise/not	Prior concerned/not	46.448	9	0

Table 10
Trust agencies/do not trust agencies

Row	Column	Chi.Sq.	DF	p-value
Trust agencies/not	Support experiments/don’t	30.032	9	0
Trust agencies/not	Locals agree /don’t	43.474	9	0
Trust agencies/not	Drought/floods risk	21.062	9	0.012
Trust agencies/not	Temperatures	34.597	9	0
Trust agencies/not	Inv. grass fire concern/not	57.813	9	0
Trust agencies/not	Inv. forb fire concern/not	67.647	9	0
Trust agencies/not	Encroachment concern/not	38.794	9	0
Trust agencies/not	Water supply concern/not	16.531	9	0.057
Trust agencies/not	Habitat	27.664	9	0.001
Trust agencies/not	Reseeding effective/not	25.842	9	0.002
Trust agencies/not	Drilling vs broadcast	25.789	9	0.002
Trust agencies/not	Agencies effective/not	41.349	9	0

Residence	Trust agencies/not	8.498	3	0.037
OHV	Trust agencies/not	20.542	12	0.058
Backpacking	Trust agencies/not	22.347	12	0.034
Future close wildfire likely	Trust agencies/not	25.467	9	0.002
Frequency state/NP recreation	Trust agencies/not	20.074	12	0.066
Crucial/naturally heal	Trust agencies/not	21.786	6	0.001
Policy realism	Trust agencies/not	33.878	6	0
Science realism	Trust agencies/not	31.679	6	0
Severity/visibility	Trust agencies/not	22.586	6	0.001
Prioritize severity/livestock	Trust agencies/not	32.628	6	0
Prefer natives/non-natives	Trust agencies/not	26.563	6	0
Public concerned/not	Trust agencies/not	26.278	9	0.002
Lar. pub. concern/not	Trust agencies/not	25.421	9	0.003
Policy precise/not	Trust agencies/not	42.862	9	0
Prior concerned/not	Trust agencies/not	52.323	9	0

Table 11

Support experiments

Row	Column	Chi.Sq.	DF	p-value
Support experiments/don't	Locals agree /don't	39.029	9	0
Support experiments/don't	Drought/floods risk	50.121	9	0
Support experiments/don't	Temperatures	33.825	9	0
Support experiments/don't	Inv. grass fire concern/not	44.67	9	0
Support experiments/don't	Inv. forb fire concern/not	26.153	9	0.002
Support experiments/don't	Encroachment concern/not	15.701	9	0.073
Support experiments/don't	Preferred seed mix	48.467	36	0.08
Support experiments/don't	Habitat	18.141	9	0.034
Support experiments/don't	Recreation	26.964	9	0.001
Support experiments/don't	Reseeding effective/not	44.308	9	0
Support experiments/don't	Seedcover effective/not	39.087	9	0
Support experiments/don't	Agencies effective/not	19.624	9	0.02
Gender	Support experiments/don't	15.604	3	0.001
Backpacking	Support experiments/don't	19.959	12	0.068
Fishing	Support experiments/don't	19.896	12	0.069
Future close wildfire likely	Support experiments/don't	18.357	9	0.031
Frequency state/NP recreation	Support experiments/don't	20.317	12	0.061
Crucial/naturally heal	Support experiments/don't	20.465	6	0.002
Policy realism	Support experiments/don't	23.851	6	0.001
Science realism	Support experiments/don't	34.881	6	0
Severity/visibility	Support experiments/don't	19.603	6	0.003
Prioritize severity/livestock	Support experiments/don't	17.305	6	0.008

Prefer natives/non-natives	Support experiments/don’t	15.798	6	0.015
Public concerned/not	Support experiments/don’t	25.599	9	0.002
Lar. pub. concern/not	Support experiments/don’t	26.532	9	0.002
Policy precise/not	Support experiments/don’t	22.035	9	0.009
Prior concerned/not	Support experiments/don’t	35.585	9	0
Trust agencies/not	Support experiments/don’t	30.032	9	0

Table 12

Locals agree /don’t with most management decisions

Row	Column	Chi.Sq.	DF	p-value
Locals agree /don’t	Drought/floods risk	32.581	9	0
Locals agree /don’t	Temperatures	46.872	9	0
Locals agree /don’t	Inv. grass fire concern/not	19.152	9	0.024
Locals agree /don’t	Inv. forb fire concern/not	16.983	9	0.049
Locals agree /don’t	Encroachment concern/not	22.808	9	0.007
Locals agree /don’t	Safe driving concern/not	17.983	9	0.035
Locals agree /don’t	Water supply concern/not	19.599	9	0.021
Locals agree /don’t	Reseeding effective/not	23.724	9	0.005
Locals agree /don’t	Seedcover effective/not	31.831	9	0
Locals agree /don’t	Drilling vs broadcast	56.783	9	0
Locals agree /don’t	Agencies effective/not	32.9	9	0
Age	Locals agree /don’t	11.222	6	0.082
Residence	Locals agree /don’t	9.457	3	0.024
Property size	Locals agree /don’t	11.133	6	0.084
Lived_region	Locals agree /don’t	15.238	9	0.085
Profession2	Locals agree /don’t	14.161	6	0.028
OHV	Locals agree /don’t	40.678	12	0
Backpacking	Locals agree /don’t	30.009	12	0.003
Frequency state/NP recreation	Locals agree /don’t	28.563	12	0.005
Public concerned/not	Locals agree /don’t	35.716	9	0
Lar. pub. concern/not	Locals agree /don’t	42.706	9	0
Policy precise/not	Locals agree /don’t	50.866	9	0
Prior concerned/not	Locals agree /don’t	29.718	9	0
Trust agencies/not	Locals agree /don’t	43.474	9	0
Support experiments/don’t	Locals agree /don’t	39.029	9	0

Table 13

Drought/floods risk

Row	Column	Chi.Sq.	DF	p-value
Drought/floods risk	Temperatures	107.167	9	0
Drought/floods risk	Inv. grass fire concern/not	27.671	9	0.001
Drought/floods risk	Inv. forb fire concern/not	27.053	9	0.001
Drought/floods risk	Safe driving concern/not	18.718	9	0.028
Drought/floods risk	Water supply concern/not	19.336	9	0.022
Drought/floods risk	Habitat	29.616	9	0.001
Drought/floods risk	Reseeding effective/not	25.523	9	0.002
Drought/floods risk	Seedcover effective/not	25.137	9	0.003
Drought/floods risk	Drilling vs broadcast	17.855	9	0.037
Own or Rent	Drought/floods risk	6.527	3	0.089
Lived_region	Drought/floods risk	18.897	9	0.026
Profession2	Drought/floods risk	12.291	6	0.056
OHV	Drought/floods risk	22	12	0.038
Camping	Drought/floods risk	20.174	12	0.064
Backpacking	Drought/floods risk	21.815	12	0.04
House miles to fire risk	Drought/floods risk	16.103	9	0.065
Future close wildfire likely	Drought/floods risk	26.689	9	0.002
Rangelands recreation	Drought/floods risk	28.357	12	0.005
Crucial/naturally heal	Drought/floods risk	16.554	6	0.011
Policy realism	Drought/floods risk	12.539	6	0.051
Science realism	Drought/floods risk	14.258	6	0.027
Severity/visibility	Drought/floods risk	11.712	6	0.069
Prioritize severity/livestock	Drought/floods risk	11.145	6	0.084
Prefer natives/non-natives	Drought/floods risk	14.748	6	0.022
Public concerned/not	Drought/floods risk	27.88	9	0.001
Lar. pub. concern/not	Drought/floods risk	16.397	9	0.059
Policy precise/not	Drought/floods risk	29.79	9	0
Prior concerned/not	Drought/floods risk	74.006	9	0
Trust agencies/not	Drought/floods risk	21.062	9	0.012
Support experiments/don’t	Drought/floods risk	50.121	9	0
Locals agree /don’t	Drought/floods risk	32.581	9	0

Table 14
Temperatures

Row	Column	Chi.Sq.	DF	p-value
Temperatures	Inv. grass fire concern/not	27.206	9	0.001
Temperatures	Inv. forb fire concern/not	20.356	9	0.016
Temperatures	Encroachment concern/not	19.673	9	0.02
Temperatures	Preferred seed mix	47.424	36	0.096
Temperatures	Safe driving concern/not	19.322	9	0.023
Temperatures	Reseeding effective/not	19.187	9	0.024
Temperatures	Drilling vs broadcast	15.447	9	0.079
Own or Rent	Temperatures	7.448	3	0.059
Fishing	Temperatures	18.979	12	0.089
Future close wildfire likely	Temperatures	33.822	9	0
Rangelands recreation	Temperatures	26.246	12	0.01
Policy realism	Temperatures	12.889	6	0.045
Science realism	Temperatures	13.732	6	0.033
Prioritize severity/livestock	Temperatures	14.183	6	0.028
Public concerned/not	Temperatures	20.246	9	0.016
Lar. pub. concern/not	Temperatures	31.499	9	0
Policy precise/not	Temperatures	28.56	9	0.001
Prior concerned/not	Temperatures	42.057	9	0
Trust agencies/not	Temperatures	34.597	9	0
Support experiments/don’t	Temperatures	33.825	9	0
Locals agree /don’t	Temperatures	46.872	9	0
Drought/floods risk	Temperatures	107.167	9	0

Table 15
Invasive grass ranking with fire concern

Row	Column	Chi.Sq.	DF	p-value
Inv. grass fire concern/not	Inv. forb fire concern/not	221.366	9	0
Inv. grass fire concern/not	Encroachment concern/not	43.349	9	0
Inv. grass fire concern/not	Preferred seed mix	54.062	36	0.027
Inv. grass fire concern/not	Erosion	17.507	9	0.041
Inv. grass fire concern/not	Forage	16.569	9	0.056
Inv. grass fire concern/not	Invasive grass concern/not	51.522	9	0
Inv. grass fire concern/not	Invasive forbs concern/not	40.691	9	0
Inv. grass fire concern/not	Reseeding effective/not	39.081	9	0
Inv. grass fire concern/not	Seedcover effective/not	25.748	9	0.002
Inv. grass fire concern/not	Drilling vs broadcast	23.898	9	0.004
Inv. grass fire concern/not	Agencies effective/not	21.772	9	0.01
Future close wildfire likely	Inv. grass fire concern/not	36.91	9	0

Crucial/naturally heal	Inv. grass fire concern/not	33.778	6	0
Policy realism	Inv. grass fire concern/not	28.495	6	0
Science realism	Inv. grass fire concern/not	34.897	6	0
Severity/visibility	Inv. grass fire concern/not	26.549	6	0
Prioritize severity/livestock	Inv. grass fire concern/not	41.297	6	0
Prefer natives/non-natives	Inv. grass fire concern/not	28.728	6	0
Public concerned/not	Inv. grass fire concern/not	25.921	9	0.002
Lar. pub. concern/not	Inv. grass fire concern/not	17.84	9	0.037
Policy precise/not	Inv. grass fire concern/not	33.411	9	0
Prior concerned/not	Inv. grass fire concern/not	46.81	9	0
Trust agencies/not	Inv. grass fire concern/not	57.813	9	0
Support experiments/don’t	Inv. grass fire concern/not	44.67	9	0
Locals agree /don’t	Inv. grass fire concern/not	19.152	9	0.024
Drought/floods risk	Inv. grass fire concern/not	27.671	9	0.001
Temperatures	Inv. grass fire concern/not	27.206	9	0.001

Table 16

Invasive forb fire concern

Row	Column	Chi.Sq.	DF	p-value
Inv. forb fire concern/not	Encroachment concern/not	65.848	9	0
Inv. forb fire concern/not	Preferred seed mix	49.945	36	0.061
Inv. forb fire concern/not	Erosion	15.137	9	0.087
Inv. forb fire concern/not	Forage	15.193	9	0.086
Inv. forb fire concern/not	Invasive grass concern/not	56.008	9	0
Inv. forb fire concern/not	Invasive forbs concern/not	69.576	9	0
Inv. forb fire concern/not	Reseeding effective/not	27.157	9	0.001
Inv. forb fire concern/not	Seedcover effective/not	17.671	9	0.039
Inv. forb fire concern/not	Drilling vs broadcast	20.931	9	0.013
Inv. forb fire concern/not	Agencies effective/not	19.943	9	0.018
Region	Inv. forb fire concern/not	9.402	3	0.024
Camping	Inv. forb fire concern/not	26.091	12	0.01
Hunting	Inv. forb fire concern/not	20.491	12	0.058
Future close wildfire likely	Inv. forb fire concern/not	22.152	9	0.008
Rangelands recreation	Inv. forb fire concern/not	22.113	12	0.036
Crucial/naturally heal	Inv. forb fire concern/not	34.949	6	0
Policy realism	Inv. forb fire concern/not	24.173	6	0
Science realism	Inv. forb fire concern/not	24.348	6	0
Severity/visibility	Inv. forb fire concern/not	21.378	6	0.002
Prioritize severity/livestock	Inv. forb fire concern/not	27.644	6	0
Prefer natives/non-natives	Inv. forb fire concern/not	26.093	6	0
Public concerned/not	Inv. forb fire concern/not	16.18	9	0.063

Lar. pub. concern/not	Inv. forb fire concern/not	18.614	9	0.029
Policy precise/not	Inv. forb fire concern/not	39.278	9	0
Prior concerned/not	Inv. forb fire concern/not	45.131	9	0
Trust agencies/not	Inv. forb fire concern/not	67.647	9	0
Support experiments/don’t	Inv. forb fire concern/not	26.153	9	0.002
Locals agree /don’t	Inv. forb fire concern/not	16.983	9	0.049
Drought/floods risk	Inv. forb fire concern/not	27.053	9	0.001
Temperatures	Inv. forb fire concern/not	20.356	9	0.016
Inv. grass fire concern/not	Inv. forb fire concern/not	221.366	9	0

Table 17

Encroachment concern

Row	Column	Chi.Sq.	DF	p-value
Encroachment concern/not	Forage	16.032	9	0.066
Encroachment concern/not	Invasive grass concern/not	17.199	9	0.046
Encroachment concern/not	Invasive forbs concern/not	17.595	9	0.04
Encroachment concern/not	Reseeding effective/not	34.285	9	0
Encroachment concern/not	Seedcover effective/not	17.514	9	0.041
Encroachment concern/not	Drilling vs broadcast	29.208	9	0.001
Gender	Encroachment concern/not	9.342	3	0.025
Raised	Encroachment concern/not	6.919	3	0.075
Own or Rent	Encroachment concern/not	12.087	3	0.007
Hiking	Encroachment concern/not	22.38	12	0.033
Backpacking	Encroachment concern/not	20.104	12	0.065
Rangelands recreation	Encroachment concern/not	26.536	12	0.009
Frequency state/NP recreation	Encroachment concern/not	24.494	12	0.017
Lar. pub. concern/not	Encroachment concern/not	31.687	9	0
Policy precise/not	Encroachment concern/not	39.593	9	0
Prior concerned/not	Encroachment concern/not	36.467	9	0
Trust agencies/not	Encroachment concern/not	38.794	9	0
Support experiments/don’t	Encroachment concern/not	15.701	9	0.073
Locals agree /don’t	Encroachment concern/not	22.808	9	0.007
Temperatures	Encroachment concern/not	19.673	9	0.02
Inv. grass fire concern/not	Encroachment concern/not	43.349	9	0
Inv. forb fire concern/not	Encroachment concern/not	65.848	9	0

Table 18

Preferred seed mix

Row	Column	Chi.Sq.	DF	p-value
Preferred seed mix	Reseeding effective/not	69.327	42	0.005
Preferred seed mix	Seedcover effective/not	56.4	42	0.068
Property size	Preferred seed mix	51.923	28	0.004
Horse Riding	Preferred seed mix	73.524	56	0.058
House miles to fire risk	Preferred seed mix	56.409	42	0.068
Years since nearby wildfire	Preferred seed mix	65.534	39	0.005
Future close wildfire likely	Preferred seed mix	56.773	42	0.064
Rangelands recreation	Preferred seed mix	78.906	56	0.024
Prioritize severity/livestock	Preferred seed mix	46.588	24	0.004
Prefer natives/non-natives	Preferred seed mix	50.21	24	0.001
Public concerned/not	Preferred seed mix	68.466	39	0.002
Prior concerned/not	Preferred seed mix	53.095	36	0.033
Support experiments/don't	Preferred seed mix	48.467	36	0.08
Temperatures	Preferred seed mix	47.424	36	0.096
Inv. grass fire concern/not	Preferred seed mix	54.062	36	0.027
Inv. forb fire concern/not	Preferred seed mix	49.945	36	0.061

Table 19

Human safety fire concern/ not

Row	Column	Chi.Sq.	DF	p-value
Human safety/not	Smoke	64.588	9	0
Human safety/not	Safe driving concern/not	50.581	9	0
Human safety/not	Water supply concern/not	22.083	9	0.009
Human safety/not	Erosion	24.269	9	0.004
Human safety/not	Forage	17.108	9	0.047
Human safety/not	Habitat	18.246	9	0.032
Human safety/not	Recreation	17.458	9	0.042
Human safety/not	Aesthetic	28.699	9	0.001
Human safety/not	Drilling vs broadcast	17.367	9	0.043
Profession2	Human safety/not	11.352	6	0.078
Horse Riding	Human safety/not	24.257	12	0.019
Fishing	Human safety/not	18.856	12	0.092
House miles to fire risk	Human safety/not	16.814	9	0.052
Crucial/naturally heal	Human safety/not	25.387	6	0
Policy realism	Human safety/not	21.221	6	0.002
Science realism	Human safety/not	23.156	6	0.001
Severity/visibility	Human safety/not	22.384	6	0.001
Prioritize severity/livestock	Human safety/not	17.956	6	0.006
Prefer natives/non-natives	Human safety/not	18.406	6	0.005

Table 20
Smoke is a concern

Row	Column	Chi.Sq.	DF	p-value
Smoke	Safe driving concern/not	81.689	9	0
Smoke	Water supply concern/not	23.184	9	0.006
Smoke	Erosion	16.059	9	0.066
Smoke	Forage	21.043	9	0.012
Smoke	Habitat	27.058	9	0.001
Smoke	Invasive grass concern/not	15.036	9	0.09
Smoke	Invasive forbs concern/not	14.773	9	0.097
Smoke	Aesthetic	43.278	9	0
Gender	Smoke	8.766	3	0.033
Own or Rent	Smoke	6.521	3	0.089
OHV	Smoke	19.68	12	0.073
Horse Riding	Smoke	20.541	12	0.058
Hunting	Smoke	28.783	12	0.004
Rangelands recreation	Smoke	23.196	12	0.026
Human safety/not	Smoke	64.588	9	0

Table 21
Safe driving is a concern

Row	Column	Chi.Sq.	DF	p-value
Safe driving concern/not	Water supply concern/not	52.077	9	0
Safe driving concern/not	Erosion	26.582	9	0.002
Safe driving concern/not	Forage	23.979	9	0.004
Safe driving concern/not	Habitat	16.495	9	0.057
Safe driving concern/not	Invasive grass concern/not	15.344	9	0.082
Safe driving concern/not	Invasive forbs concern/not	18.448	9	0.03
Safe driving concern/not	Recreation	28.383	9	0.001
Safe driving concern/not	Aesthetic	29.076	9	0.001
Education	Safe driving concern/not	15.146	9	0.087
Hunting	Safe driving concern/not	21.741	12	0.041
Fishing	Safe driving concern/not	19.571	12	0.076
Policy precise/not	Safe driving concern/not	17.835	9	0.037
Prior concerned/not	Safe driving concern/not	15.159	9	0.087
Locals agree /don’t	Safe driving concern/not	17.983	9	0.035
Drought/floods risk	Safe driving concern/not	18.718	9	0.028
Temperatures	Safe driving concern/not	19.322	9	0.023
Human safety/not	Safe driving concern/not	50.581	9	0
Smoke	Safe driving concern/not	81.689	9	0

Table 22
Water supply is a concern

Row	Column	Chi.Sq.	DF	p-value
Water supply concern/not	Erosion	73.176	9	0
Water supply concern/not	Forage	17.8	9	0.038
Water supply concern/not	Habitat	42.138	9	0
Water supply concern/not	Invasive grass concern/not	32.753	9	0
Water supply concern/not	Invasive forbs concern/not	28.304	9	0.001
Water supply concern/not	Recreation	25.489	9	0.002
Water supply concern/not	Aesthetic	35.043	9	0
Water supply concern/not	Agencies effective/not	23.298	9	0.006
Horse Riding	Water supply concern/not	23.372	12	0.025
Prefer natives/non-natives	Water supply concern/not	9.715	3	0.021
Public concerned/not	Water supply concern/not	21.955	9	0.009
Policy precise/not	Water supply concern/not	15.467	9	0.079
Trust agencies/not	Water supply concern/not	16.531	9	0.057
Locals agree /don’t	Water supply concern/not	19.599	9	0.021
Drought/floods risk	Water supply concern/not	19.336	9	0.022
Human safety/not	Water supply concern/not	22.083	9	0.009
Smoke	Water supply concern/not	23.184	9	0.006
Safe driving concern/not	Water supply concern/not	52.077	9	0

Table 23
Erosion is a concern

Row	Column	Chi.Sq.	DF	p-value
Erosion	Forage	92.453	9	0
Erosion	Habitat	67.353	9	0
Erosion	Invasive grass concern/not	46.522	9	0
Erosion	Invasive forbs concern/not	29.437	9	0.001
Erosion	Recreation	22.708	9	0.007
Erosion	Aesthetic	27.934	9	0.001
Education	Erosion	16.37	9	0.06
Science realism	Erosion	11.484	6	0.075
Inv. grass fire concern/not	Erosion	17.507	9	0.041
Inv. forb fire concern/not	Erosion	15.137	9	0.087
Human safety/not	Erosion	24.269	9	0.004
Smoke	Erosion	16.059	9	0.066
Safe driving concern/not	Erosion	26.582	9	0.002
Water supply concern/not	Erosion	73.176	9	0

Table 24
Forage is a concern

Row	Column	Chi.Sq.	DF	p-value
Forage	Habitat	109.006	9	0
Forage	Invasive grass concern/not	43.737	9	0
Forage	Invasive forbs concern/not	32.824	9	0
Forage	Recreation	28.266	9	0.001
Forage	Aesthetic	27.34	9	0.001
Forage	Reseeding effective/not	14.726	9	0.099
Lived_community	Forage	15.862	9	0.07
Camping	Forage	21.546	12	0.043
Severity/visibility	Forage	12.06	6	0.061
Inv. grass fire concern/not	Forage	16.569	9	0.056
Inv. forb fire concern/not	Forage	15.193	9	0.086
Encroachment concern/not	Forage	16.032	9	0.066
Human safety/not	Forage	17.108	9	0.047
Smoke	Forage	21.043	9	0.012
Safe driving concern/not	Forage	23.979	9	0.004
Water supply concern/not	Forage	17.8	9	0.038
Erosion	Forage	92.453	9	0

Table 25
Habitat is a concern

Row	Column	Chi.Sq.	DF	p-value
Habitat	Invasive grass concern/not	42.294	9	0
Habitat	Invasive forbs concern/not	32.968	9	0
Habitat	Recreation	26.758	9	0.002
Habitat	Aesthetic	20.092	9	0.017
Habitat	Agencies effective/not	15.185	9	0.086
Hunting	Habitat	19.533	12	0.076
Crucial/naturally heal	Habitat	13.399	6	0.037
Severity/visibility	Habitat	27.043	6	0
Lar. pub. concern/not	Habitat	16.278	9	0.061
Trust agencies/not	Habitat	27.664	9	0.001
Support experiments/don’t	Habitat	18.141	9	0.034
Drought/floods risk	Habitat	29.616	9	0.001
Human safety/not	Habitat	18.246	9	0.032
Smoke	Habitat	27.058	9	0.001
Safe driving concern/not	Habitat	16.495	9	0.057
Water supply concern/not	Habitat	42.138	9	0
Erosion	Habitat	67.353	9	0
Forage	Habitat	109.006	9	0

Table 26
Invasive grass is a concern

Row	Column	Chi.Sq.	DF	p-value
Invasive grass concern/not	Invasive forbs concern/not	225.122	9	0
Invasive grass concern/not	Recreation	28.564	9	0.001
Invasive grass concern/not	Aesthetic	20.665	9	0.014
Region	Invasive grass concern/not	11.553	3	0.009
Raised	Invasive grass concern/not	11.292	3	0.01
Education	Invasive grass concern/not	17.655	9	0.039
Profession2	Invasive grass concern/not	10.864	6	0.093
Hunting	Invasive grass concern/not	18.675	12	0.097
Future close wildfire likely	Invasive grass concern/not	29.618	9	0.001
Crucial/naturally heal	Invasive grass concern/not	11.959	6	0.063
Severity/visibility	Invasive grass concern/not	14.847	6	0.021
Prioritize severity/livestock	Invasive grass concern/not	22.927	6	0.001
Prefer natives/non-natives	Invasive grass concern/not	11.247	6	0.081
Prior concerned/not	Invasive grass concern/not	20.301	9	0.016
Inv. grass fire concern/not	Invasive grass concern/not	51.522	9	0
Inv. forb fire concern/not	Invasive grass concern/not	56.008	9	0
Encroachment concern/not	Invasive grass concern/not	17.199	9	0.046
Smoke	Invasive grass concern/not	15.036	9	0.09
Safe driving concern/not	Invasive grass concern/not	15.344	9	0.082
Water supply concern/not	Invasive grass concern/not	32.753	9	0
Erosion	Invasive grass concern/not	46.522	9	0
Forage	Invasive grass concern/not	43.737	9	0
Habitat	Invasive grass concern/not	42.294	9	0

Table 27
Invasive forbs concern

Row	Column	Chi.Sq.	DF	p-value
Invasive forbs concern/not	Recreation	32.788	9	0
Raised	Invasive forbs concern/not	10.065	3	0.018
Severity/visibility	Invasive forbs concern/not	16.821	6	0.01
Prioritize severity/livestock	Invasive forbs concern/not	23.256	6	0.001
Prefer natives/non-natives	Invasive forbs concern/not	12.541	6	0.051
Prior concerned/not	Invasive forbs concern/not	15.361	9	0.081
Inv. grass fire concern/not	Invasive forbs concern/not	40.691	9	0
Inv. forb fire concern/not	Invasive forbs concern/not	69.576	9	0
Encroachment concern/not	Invasive forbs concern/not	17.595	9	0.04
Smoke	Invasive forbs concern/not	14.773	9	0.097
Safe driving concern/not	Invasive forbs concern/not	18.448	9	0.03

Water supply concern/not	Invasive forbs concern/not	28.304	9	0.001
Erosion	Invasive forbs concern/not	29.437	9	0.001
Forage	Invasive forbs concern/not	32.824	9	0
Habitat	Invasive forbs concern/not	32.968	9	0
Invasive grass concern/not	Invasive forbs concern/not	225.122	9	0

Table 28
Recreation is a concern

Row	Column	Chi.Sq.	DF	p-value
Recreation	Aesthetic	91.161	9	0
Gender	Recreation	18.729	3	0
Backpacking	Recreation	18.698	12	0.096
House miles to fire risk	Recreation	15.93	9	0.068
Rangelands recreation	Recreation	21.002	12	0.05
Prior concerned/not	Recreation	19.396	9	0.022
Support experiments/don’t	Recreation	26.964	9	0.001
Human safety/not	Recreation	17.458	9	0.042
Safe driving concern/not	Recreation	28.383	9	0.001
Water supply concern/not	Recreation	25.489	9	0.002
Erosion	Recreation	22.708	9	0.007
Forage	Recreation	28.266	9	0.001
Habitat	Recreation	26.758	9	0.002
Invasive grass concern/not	Recreation	28.564	9	0.001
Invasive forbs concern/not	Recreation	32.788	9	0

Table 29
Aesthetic is a concern

Row	Column	Chi.Sq.	DF	p-value
Age	Aesthetic	16.034	6	0.014
Own or Rent	Aesthetic	6.916	3	0.075
Education	Aesthetic	16.846	9	0.051
Horse Riding	Aesthetic	20.073	12	0.066
Rangelands recreation	Aesthetic	20.748	12	0.054
Prior concerned/not	Aesthetic	17.687	9	0.039
Human safety/not	Aesthetic	28.699	9	0.001
Smoke	Aesthetic	43.278	9	0
Safe driving concern/not	Aesthetic	29.076	9	0.001
Water supply concern/not	Aesthetic	35.043	9	0
Erosion	Aesthetic	27.934	9	0.001
Forage	Aesthetic	27.34	9	0.001
Habitat	Aesthetic	20.092	9	0.017

Invasive grass concern/not	Aesthetic	20.665	9	0.014
Recreation	Aesthetic	91.161	9	0

Table 30
Reseeding is effective

Row	Column	Chi.Sq.	DF	p-value
Reseeding effective/not	Seedcover effective/not	85.451	9	0
Reseeding effective/not	Drilling vs broadcast	16.489	9	0.057
Region	Reseeding effective/not	18.929	3	0
Property size	Reseeding effective/not	12.419	6	0.053
Own or Rent	Reseeding effective/not	13.062	3	0.005
Fishing	Reseeding effective/not	19.265	12	0.082
Future close wildfire likely	Reseeding effective/not	17.684	9	0.039
Rangelands recreation	Reseeding effective/not	19.381	12	0.08
Crucial/naturally heal	Reseeding effective/not	40.279	6	0
Policy realism	Reseeding effective/not	23.208	6	0.001
Science realism	Reseeding effective/not	30.193	6	0
Severity/visibility	Reseeding effective/not	17.342	6	0.008
Prioritize severity/livestock	Reseeding effective/not	20.154	6	0.003
Prefer natives/non-natives	Reseeding effective/not	20.815	6	0.002
Public concerned/not	Reseeding effective/not	16.734	9	0.053
Lar. pub. concern/not	Reseeding effective/not	38.045	9	0
Policy precise/not	Reseeding effective/not	23.043	9	0.006
Prior concerned/not	Reseeding effective/not	25.245	9	0.003
Trust agencies/not	Reseeding effective/not	25.842	9	0.002
Support experiments/don’t	Reseeding effective/not	44.308	9	0
Locals agree /don’t	Reseeding effective/not	23.724	9	0.005
Drought/floods risk	Reseeding effective/not	25.523	9	0.002
Temperatures	Reseeding effective/not	19.187	9	0.024
Inv. grass fire concern/not	Reseeding effective/not	39.081	9	0
Inv. forb fire concern/not	Reseeding effective/not	27.157	9	0.001
Encroachment concern/not	Reseeding effective/not	34.285	9	0
Preferred seed mix	Reseeding effective/not	69.327	42	0.005
Forage	Reseeding effective/not	14.726	9	0.099

Table 31
Seedcover is effective/not

Row	Column	Chi.Sq.	DF	p-value
Seedcover effective/not	Drilling vs broadcast	59.152	9	0
Seedcover effective/not	Agencies effective/not	34.002	9	0
Gender	Seedcover effective/not	7.145	3	0.067
Residence	Seedcover effective/not	10.184	3	0.017
Property size	Seedcover effective/not	12.56	6	0.051
OHV	Seedcover effective/not	34.447	12	0.001
Backpacking	Seedcover effective/not	24.46	12	0.018
Hunting	Seedcover effective/not	26.122	12	0.01
Fishing	Seedcover effective/not	20.026	12	0.067
Science realism	Seedcover effective/not	12.939	6	0.044
Public concerned/not	Seedcover effective/not	17.058	9	0.048
Lar. pub. concern/not	Seedcover effective/not	24.511	9	0.004
Policy precise/not	Seedcover effective/not	17.011	9	0.049
Prior concerned/not	Seedcover effective/not	15.72	9	0.073
Support experiments/don’t	Seedcover effective/not	39.087	9	0
Locals agree /don’t	Seedcover effective/not	31.831	9	0
Drought/floods risk	Seedcover effective/not	25.137	9	0.003
Inv. grass fire concern/not	Seedcover effective/not	25.748	9	0.002
Inv. forb fire concern/not	Seedcover effective/not	17.671	9	0.039
Encroachment concern/not	Seedcover effective/not	17.514	9	0.041
Preferred seed mix	Seedcover effective/not	56.4	42	0.068
Reseeding effective/not	Seedcover effective/not	85.451	9	0

Table 32
Drilling is more effective than broadcast seeding

Row	Column	Chi.Sq.	DF	p-value
Drilling vs broadcast	Agencies effective/not	52.298	9	0
Gender	Drilling vs broadcast	6.929	3	0.074
Property size	Drilling vs broadcast	14.819	6	0.022
OHV	Drilling vs broadcast	19.396	12	0.079
Horse Riding	Drilling vs broadcast	24.801	12	0.016
Hunting	Drilling vs broadcast	31.447	12	0.002
Fishing	Drilling vs broadcast	30.71	12	0.002
Years since nearby wildfire	Drilling vs broadcast	22.684	9	0.007
Future close wildfire likely	Drilling vs broadcast	23.812	9	0.005
Public concerned/not	Drilling vs broadcast	26.434	9	0.002
Lar. pub. concern/not	Drilling vs broadcast	15.576	9	0.076
Policy precise/not	Drilling vs broadcast	18.683	9	0.028

Prior concerned/not	Drilling vs broadcast	28.398	9	0.001
Trust agencies/not	Drilling vs broadcast	25.789	9	0.002
Locals agree /don’t	Drilling vs broadcast	56.783	9	0
Drought/floods risk	Drilling vs broadcast	17.855	9	0.037
Temperatures	Drilling vs broadcast	15.447	9	0.079
Inv. grass fire concern/not	Drilling vs broadcast	23.898	9	0.004
Inv. forb fire concern/not	Drilling vs broadcast	20.931	9	0.013
Encroachment concern/not	Drilling vs broadcast	29.208	9	0.001
Human safety/not	Drilling vs broadcast	17.367	9	0.043
Reseeding effective/not	Drilling vs broadcast	16.489	9	0.057
Seedcover effective/not	Drilling vs broadcast	59.152	9	0

Table 33

Agencies effectiveness

Row	Column	Chi.Sq.	DF	p-value
Age	Agencies effective/not	15.647	6	0.016
OHV	Agencies effective/not	19.453	12	0.078
Camping	Agencies effective/not	18.83	12	0.093
Future close wildfire likely	Agencies effective/not	16.565	9	0.056
Public concerned/not	Agencies effective/not	17.967	9	0.036
Policy precise/not	Agencies effective/not	16.858	9	0.051
Prior concerned/not	Agencies effective/not	23.867	9	0.005
Trust agencies/not	Agencies effective/not	41.349	9	0
Support experiments/don’t	Agencies effective/not	19.624	9	0.02
Locals agree /don’t	Agencies effective/not	32.9	9	0
Inv. grass fire concern/not	Agencies effective/not	21.772	9	0.01
Inv. forb fire concern/not	Agencies effective/not	19.943	9	0.018
Water supply concern/not	Agencies effective/not	23.298	9	0.006
Habitat	Agencies effective/not	15.185	9	0.086
Seedcover effective/not	Agencies effective/not	34.002	9	0
Drilling vs broadcast	Agencies effective/not	52.298	9	0

APPENDIX D

BIOLOGICAL SOIL CRUST

FIELD AND LAB NOTES

Table 1

Plant and biological soil crust species at each morphological BSC excavation site, in Rush Valley, UT, October 2014. Biological soil crusts were identified using: Rosentreter, R., Bowker, M. and Belnap, J., 2007. A field guide to biological soil crusts of western US drylands: Common lichens and bryophytes. *Bureau of Land Management*. Grasses were confirmed with: Grasses and grasslike plants of Utah: a field guide (Banner, R.E., Pratt, M. and Bowns, J., 2011 2nd Edition Utah State University Cooperative Extension)

	Vegetation	**Biological soil crusts**
M1) • large gaps between shrubs • low abundance of grasses	• *Artemesia tridentata ssp. wyomingensis* • *Elymus elymoides* • *Bromus tectorum* • dead grasses/ dead forbs • Unknown forb	• very flat, minimal rippling cyanobacteria, possibly *Microcoleus vaginatus* • no lichens or mosses present
M2) • large gaps between shrubs • slightly more grasses than M1	• *Artemesia tridentata ssp. Wyomingensis* • *Bromus tectorum* • *Pseudoroegneria spicata* • Dead grasses / dead forbs • Unknown forb	• rippled cyanobacteria, possibly *Microcoleus vaginatus* • *Collema* spp. (black, gelatinous, minutely foliose lichen; nitrogen fixing) • 1 small patch of *Bryum argentum* (short moss) • 1 small cluster of *Caloplaca tominii* on a twig (orange crustose lichen)
M3) • Shrub gap small • Most grasses and forbs in shrub interspace compared to any other group (mostly PSSP)	• *Artemesia tridentata ssp. wyomingensis* • *Pseudoroegneria spicata* • *Bromus tectorum* • *Atriplex confertifolia* • *Ipomopsis congesta* • Unknown cactus	• Sporadic pinnacled (not continuous) • *Collema* spp. (black, gelatinous, minutely foliose lichen; nitrogen fixing) • *Lepraria* spp? (white crustose lichen) • *Bryum argentum* (short moss,

	• Dead grasses/ dead forbs	generalist) • *Psora cerebriformis* (white squamulose lichen) • *Placidium lacinulatum* (brown squamulose lichen
M4) – dominated by nitrogen fixing *Collema* • Shrub gap small • more grasses and forbs than M2	• *Artemesia tridentata ssp. wyomingensis* • *Pseudoroegneria spicata* • *Elymus elymoides* • *Bromus tectorum* • *Acchilea millefolium* var *Occidentalis*	• More heavily pinnacled than M3, continuous, • *Collema* spp. (black, gelatinous, minutely foliose lichen; nitrogen fixing) • *Lepraria* spp? (white crustose lichen) • *Psora decipens* (pink/red squamulose lichen) • *Bryum argentum* (short moss) • *Psora cerebriformis* (white squamulose lichen) • *Placidium lacinulatum* (brown squamulose lichen
M5) • Undershrubs, collected for a couple of different shrubs • Grasses seemed to be mostly PSSP and BRTE	• *Atridentata ssp. wyomingensis* • *Pseudoroegneria spicata* • *Bromus tectorum* • Dead grasses/ dead forbs	• *Syntrichia ruralis* – tall moss • Possibly some minimal cyanobateria (e.g. *Microcoleus vaginatus*), very little structural integrity however • small peripheral patches of *Bryum argentum* (silver tipped short moss) and *Bryum caespiticium* (yellow tipped short moss).

Table 2

Greenhouse Seed Origin, Seed Viability Tests, and Planting Depth

Species	Origin	Details	Germination Test 2014
Hesperostipa comata:	Utah's Watershed Restoration Initiative, UTDNR-WR Great Basin Research Center, Ephraim, UT -	87.68% pure seed, 11.78% inert, 0.12% weeds, 0.42% other crop seed. 95% germination, 92.29% purity. Lot gbrc-sh-	37.25%

	Beaver I Species Lot: 09014-R	mcgs-10. Origin UT, tested 09/09.	
Sphaeralcea grossulariifolia:	Stevenson Intermountain Seed, Inc. Box 2, Utah 84627 (435)283-6639.	97.69% pure, 2.16% inert, 0.15% weed, 89% germination. Lot 08039 Origin Washington, UT Test dated 09/16/09.	63.5%
Elymus elymoides 'Rattlesnake'.	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2010	32%
Pseudoroegneria spicata	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2010	83.75%
Achnatherum hymenoides 'Rimrock'	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2011	20%
A. hymenoides 'G3' White River Ft Green Farm	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2011	20%
Bromus tectorum	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2012	70.5%
Acchillea millefollium var *Occidentalis*	USDA ARS Forage and Range Research Laboratory in Logan, UT	Cache and Box Elder County, 2011	91.25%

General Plant Characteristics

The following characteristics are from the United State Department of Agriculture Plants Database Plant Guides. http://plants.usda.gov/java/

Bluebunch wheatgrass (*Pseudoroegneria spicata*) extensive fibrous roots ; ¼ - ¾ in planting depth (fine-coarse) ; medium to coarse soil that is >10 feet? Deep. Elevation 152-3048 m. Precipitation 10-20" (secar down to 8"). Prechill, YES. Long lived, intolerant of poor drainage, fast developer.

Bottlebrush squirreltail (*Elymus elymoides*) 'rattlesnake' (2010), ¼ - ½ inch planting depth. Prefers medium to fine soil and also does well in coarse and gravelly. 600-3500 m elevation, 8-10 + in precipitation. NO prechill. C3, early seral, self-fertilizing, fire resistant.

Indian ricegrass (*Achnatherum hymenoides*) 'rimrock' fibrous rooted, ½ - 1 in planting depth on medium textured soils, 1-3" coarse. The deeper it is planted, the more likely it will be adequately stratified, and less likely to be eaten by rodents. Not a good broadcast candidate. Found on sandy coarse soils, but also found on loams. 1006-2896 m, 8-14" (as low as 6"). 4-6 years old, moist-stratify for 30 days. If younger, sandpaper + 6-10 month moist stratification. Does not tolerate poorly drained soils. Rimrock cultivar can retain mature seed better.

Needle-and-threadgrass (*Hesperostipa comata*) ½ - 1 in (clay-sand). Prefers fine sandy/ coarse gravelly loams. Also found on loams and clay loams. 1067-2591 m (also 305 m?), typically 7-16" (sometimes 5-24"). NO prechill (contraindicated). > 2 years old is best.

Western yarrow (*Achillea millefolium* L. var. *occidentalis*) moderately rhizomatous. 1/8-1/4 in deep, or broadcast. Highly variable soil types: gravelly loam, thin or sandy, droughty soils. No prechill needed. Early seral, readily establishes, not to be confused with common yarrow, 75% germinate in 5 days.
Gooseberry globemallow (*Sphaeralcea grossulariifolia*) taproot (and rhizomatous?). 1/8-1/4 in. Clay and gravel soils, moderately alkali tolerant (saline to sodic). 800-2300m , 6-12+". Drill or broadcast. Scarification and boil or soak (soak looks higher, see plant guide for further details). No prechill needed after that.

Soils

More developed biological soil crusts: Top soil 0-7cm, pinnacled BSC, gravelly

A Horizon 7-20cm: pale brown (10YR 6/3) sandy loam, brown (10 YR 5/3) moist; weak, medium, granular/platy structure (class 3), slightly sticky, slightly plastic, many fine and medium roots; 15% gravel; strongly effervescent; moderately alkaline; (pH 8.2); clear, wavy boundary (10-30cm thick).

B horizon 20-50cm; very pale brown (10YR 7/3) loam, brown (10 YR 5/3) moist; moderate, fine, blocky structure (class 4), slightly sticky, slightly plastic; fine and medium roots; 5% gravel; strongly effervescent; moderately alkaline; (pH 8.2); clear wavy boundary. (10-30 cm thick)

Less developed biological soil crusts: Top soil 0-0.5cm, rippled BSC, gravelly

A Horizon 0-7cm: very pale brown (10YR 7/3) sandy loam, pale brown (10 YR 6/3) moist; weak, thin, granular/platy structure (class 2), slightly sticky, slightly plastic, < 5% gravel; strongly effervescent; moderately alkaline; (pH 8.2); clear, wavy boundary (3-7cm thick).

B horizon 7-30cm; very pale brown (10YR 7/3) loam, pale brown (10 YR 6/3) moist; moderate, fine, blocky structure (class 4), slightly sticky, slightly plastic; fine, medium, and large roots; strongly effervescent; moderately alkaline; (pH 8.2); clear wavy boundary (10-30 cm thick).

Soils lab

Colorimetric pH assessed with both thymol blue and phenol (all samples pH 8.2, double checked with lab)

Bulk density samples excavated with a metal ring (diameter 8.8cm, ht 5.2 cm, air dry radius = $\pi 4.4^2 5.2 = 316.27 \text{ cm}^3$). Reference bulk density of USDA Taylorsflat loam is 1.30 g/cm^3. Intact BSC: Wet: 1.14 g/cm^3 Dry: 1.04 g/cm^3. Degraded BSC: Wet: 1.27 g/cm^3 Dry: 1.15 g/cm^3. As expected, both wet and dry bulk density was slightly higher on the more degraded soils.

Electrical conductivity (EC) was tested with an Accumet excel XL30 conductivity meter. Soil Survey Staff (2013) official series description of Taylorsflat loam indicates, EC can range from 0-4 dS/m.
Standard: 10.05 μS/cm (microsiemens)
Distilled water: 31.43 μS/cm
Intact BSC 7-20cm 326.7 μS/cm-31.43 = 295.27 = 0.003 dS/m
Intact BSC 20-50cm: 1.695 **m**S/cm = 1.664 dS/m
Degraded BSC 0-7cm: 194.6 μS/cm = 163.17 μS/cm = 0.0016 dS/m

Degraded BSC 7-30cm: 177.2 μS/cm = 145.77 μS/cm = 0.0015 dS/m

Soil texture classes settled out: ~ 2 mm clay (20%), ~ 6mm sand (60%), ~ 2 mm silt (20%) = sandy loam
Taylorsflat loam: 40% sand, 38% silt; 22.5% clay; = loam
Other dominant soils: 45-54% sand, 35-41% silt; ~ 12% clay = loam to sandy loam,

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available online at: https://soilseries.sc.egov.usda.gov/OSD_Docs/T/TAYLORSFLAT.html. Accessed [November/5/2013].

APPENDIX E

GREENHOUSE DATA

Seeding strategy tables. BC = broadcast, MD = “minimum-till” treatment, RD = “range drilled” treatment.
Transformations: Ovdisp = overdispersed, sqrt = square root, LSmeans = lsmeans due to significant interaction. Chisq = Chi-squared, DF = degrees of freedom, p-val = p-value. Score = Number of significant treatments within each BSC group. ***Mean*** = overall mean.

Table 1
All native species emergence

All natives	Ovdisp			BSC	Mean and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
emerged	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	1.95	8	0.983	M1	0.30	0.32	0.30	-0.41,	166,	0.6825	-0.04,	166,	0.9667	0.37	166,	0.7106
				±	0.04	0.04	0.04									
Morphology	2.97	4	0.562	M2	0.27	0.43	0.35	-2.69,	166,	0.0079*	-1.26,	166,	0.2084	1.43,	166,	0.1553
				±	0.04	0.04	0.04									
Rx	2.10	2	0.350	M3	0.36	0.42	0.41	-0.87,	166,	0.3832	-0.69,	166,	0.4932	0.21,	166,	0.8362
				±	0.04	0.04	0.04									
				M4	0.29	0.44	0.35	-2.39,	164,	0.0179*	-0.98,	164,	0.3309	1.59,	158,	0.1136
				±	0.04	0.05	0.04									
				M5	0.27	0.29	0.32	-0.46,	166,	0.6435	-0.91,	165,	0.3642	-0.44,	165,	0.6601
				±	0.04	0.04	0.04									
				Mean	29.8	38	34.6									
				Score	0	2	0									

Table 2
All native species survival

All natives	Sqrt LSmeans			BSC	Mean and SE			***MD v BC***			***RD v. BC***			***RD v. MD***		
survived	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	DF	z	p-val	DF	z	p-val	DF	z	p-val
Interaction	14.82	8	0.0627	M1	0.26	0.30	0.23	15	0.576	0.8346	15	-0.649	0.7956	15	-1.226	0.4570
				±	0.04	0.04	0.04									
Morphology	22.32	4	0.0002	M2	0.20	0.46	0.41	15	3.543	0.0078*	15	2.719	0.0397*	15	-0.824	0.6946
				±	0.04	0.05	0.05									
Rx	10.60	2	0.005	M3	0.43	0.49	0.50	15	0.691	0.7720	15	0.910	0.6423	15	0.219	0.9740
				±	0.04	0.04	0.04									
				M4	0.35	0.43	0.45	15	0.933	0.6284	15	1.548	0.2979	15	0.614	0.8146
				±	0.04	0.04	0.04									
				M5	0.28	0.35	0.35	15	1.012	0.5809	15	1.053	0.5566	15	0.041	0.9991
				±	0.04	0.04	0.04									
				Mean	30.4	40.6	38.8									
				Score	0	1	1									

*This essentially shows no treatment was better in final harvest.

Table 3

Bluebunch wheatgrass emergence: model significance and treatment significance within BSC groups

	LSmeans			BSC	Means and SE			***MD v BC***		***RD v. BC***		***RD v. MD***	
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	z	p-val	z	p-val	z	p-val
Interaction	16.22	8	*	M1	0.44	0.61	0.48	1.66	0.2195	0.45	0.8933	-1.22	0.4441
				±	0.08	0.06	0.07						
Morphology	19.74	4	***	M2	0.52	0.85	0.80	3.52	0.0013*	2.77	0.0155*	-0.79	0.7064
				±	0.04	0.05	0.04						
Rx	15.06	2	***	M3	0.81	0.87	0.75	0.80	0.7022	-0.63	0.8056	-1.43	0.3264
				±	0.05	0.03	0.06						
				M4	0.46	0.94	0.68	5.55	< 0.0001*	2.48	0.0346	-3.21	0.0038*
				±	0.08	0.02	0.08						
				M5	0.48	0.60	0.48	1.12	0.5037	-0.08	0.9962	-1.20	0.4527
				±	0.06	0.07	0.05						
				Mean	54.2	77.4	63.8						
				Score	0	3	2						

Table 4

Bluebunch wheatgrass survival: model significance and treatment significance within BSC groups

	Chisq	DF	p-val	BSC	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
				Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	4.30	8	0.829	M1	0.64	0.91	0.73	-2.09	16	0.0534*	-0.58	24	0.5678	1.86	19	0.0788*
				±	0.12	0.04	0.09									
Morphology	6.53	4	0.163	M2	0.91	0.96	0.96	-0.75	26	0.459	-1.05	24	0.3020	-0.14	23	0.8913
				±	0.04	0.04	0.03									
Rx	3.69	2	0.158	M3	0.98	0.99	0.85	-0.39	22	0.6995	2.21	15	0.0435*	2.38	14	0.03238*
				±	0.02	0.01	0.06									
				M4	0.62	0.93	0.83b	-2.50	18	0.0226*	-1.59	21	0.1261	1.24	24	0.2256
				±	0.11	0.05	0.06									
				M5	0.74	0.83	0.81	-0.98	26	0.3347	-0.66	24	0.5128	0.22	25	0.8355
				±	0.06	0.07	0.08									
				Mean	77.8	92.4	83.6									
				Score	1	4	0									

Table 5

Bluebunch wheatgrass emerged LS means (BSC group significance within treatments)

BC	contrast		estimate	SE	DF	z.ratio	p-value	***
	M2	M1	0.49	0.59	NA	0.83	0.9214	
	M3	M1	2.24	0.61	NA	3.69	0.0021	***
	M3	M2	1.76	0.60	NA	2.92	0.0286	**
	M4	M1	0.16	0.59	NA	0.28	0.9987	
	M4	M2	-0.32	0.59	NA	-0.55	0.9816	
	M4	M3	-2.08	0.61	NA	-3.43	0.0055	**
	M5	M1	0.32	0.59	NA	0.54	0.9830	
	M5	M2	-0.17	0.58	NA	-0.29	0.9985	
	M5	M3	-1.92	0.60	NA	-3.20	0.0122	**
	M5	M4	0.16	0.59	NA	0.26	0.9989	
Minimum-till								
	M2	M1	1.65	0.61	NA	2.69	0.0555	*
	M3	M1	1.76	0.61	NA	2.87	0.0332	**
	M3	M2	0.11	0.64	NA	0.18	0.9998	
	M4	M1	2.87	0.66	NA	4.34	0.0001	***
	M4	M2	1.22	0.68	NA	1.78	0.3826	
	M4	M3	1.10	0.68	NA	1.62	0.4856	
	M5	M1	-0.01	0.59	NA	-0.02	1	
	M5	M2	-1.66	0.61	NA	-2.70	0.0535	**
	M5	M3	-1.77	0.61	NA	-2.89	0.0320	**
	M5	M4	-2.88	0.66	NA	-4.35	0.0001	***
RD drilled								
	M2	M1	1.87	0.60	NA	3.11	0.016	**
	M3	M1	1.59	0.60	NA	2.65	0.0617	*
	M3	M2	-0.28	0.61	NA	-0.46	0.9907	
	M4	M1	1.41	0.61	NA	2.32	0.1392	!
	M4	M2	-0.46	0.62	NA	-0.74	0.9464	
	M4	M3	-0.18	0.62	NA	-0.29	0.9985	
	M5	M1	0.002	0.58	NA	0.005	1	
	M5	M2	-1.87	0.60	NA	-3.13	0.0152	**
	M5	M3	-1.59	0.60	NA	-2.66	0.0597	*
	M5	M4	-1.41	0.61	NA	-2.33	0.1358	!

Table 6

Bluebunch wheatgrass Survival LS means (BSC group significance within treatments)

BC	contrast		t	DF	p-val	
	M1	M2	-2.16	16	0.04669	**
	M1	M3	-2.78	13	0.01528	**
	M1	M4	0.13	26	0.8975	
	M1	M5	-0.75	19	0.4608	
	M2	M3	-1.58	17	0.1319	!
	M2	M4	2.46	16	0.02581	**
	M2	M5	2.51	22	0.0199	**
	M3	M4	3.13	13	0.007646	**
	M3	M5	3.98	15	0.001219	***
	M4	M5	-0.96	19	0.3494	
Minimum-till						
	M1	M2	-0.84	26	0.4081	
	M1	M3	-1.86	14	0.08409	*
	M1	M4	-0.34	25	0.7392	
	M1	M5	1.01	22	0.3228	
	M2	M3	-0.65	14	0.5258	
	M2	M4	0.44	26	0.6627	
	M2	M5	1.64	22	0.1157	!
	M3	M4	1.15	14	0.2675	
	M3	M5	2.36	14	0.03373	**
	M4	M5	1.22	24	0.2333	
RD drilled						
	M1	M2	-2.58	16	0.0203	**
	M1	M3	-1.18	22	0.2524	
	M1	M4	-0.93	24	0.3631	
	M1	M5	-0.67	26	0.5067	
	M2	M3	1.81	19	0.0861	*
	M2	M4	1.93	18	0.06956	*
	M2	M5	1.89	17	0.0768	*
	M3	M4	0.25	26	0.8036	
	M3	M5	0.45	24	0.66	
	M4	M5	0.21	25	0.8338	

Table 7

Bottlebrush squirreltail emergence: model significance and treatment significance within BSC groups

				BSC	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	8.411	8	0.3944	M1	0.02	0.02	0.02	0	23	1	0.24	23	0.8154	0.30	26	0.7701
				±	0.01	0.01	0.01									
Morphology	14.061	4	0.0071 **	M2	0.02	0.09	0.04	-3.70	24	0.0011*	-1.20	25	0.2406	2.41	26	0.0236*
				±	0.01	0.02	0.01									
Rx	3.4166	2	0.1812	M3	0.04	0.04	0.06	0	25	1	-0.94	24	0.3546	-0.85	26	0.4027
				±	0.01	0.01	0.01									
				M4	0.06	0.07	0.08	-0.46	23	0.6474	-0.70	26	0.4894	-0.11	24	0.9111
				±	0.02	0.03	0.02									
				M5	0.03	0.03	0.05	-0.14	26	0.8864	-0.65	25	0.5194	-0.51	25	0.6114
				±	0.02	0.02	0.02									
				Mean	3.4	5	5									
				Score	0	2	0									

Very low emerged overall, < 10%

Table 8
Bottlebrush squirreltail survival: model significance and treatment significance within BSC groups

	Sqrt			BSC	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	7.0085	8	0.5357	M1	0.04	0.04	0.04	-0.41	26	0.6818	-0.09	26	0.9296	0.35	26	0.728
				±	0.03	0.02	0.02									
Morphology	13.97	4	0.0074 **	M2	0.04a	0.13b	0.06a	-2.79	26	0.0096*	-0.99	26	0.3297	1.79	26	0.0846*
				±	0.02	0.03	0.02									
Rx	2.5569	2	0.2785	M3	0.09	0.09	0.12	0.37	25	0.7158	-0.76	26	0.4557	-1.05	26	0.3015
				±	0.02	0.03	0.03									
				M4	0.11	0.14	0.14	-0.11	26	0.914	-0.77	26	0.4456	-0.61	25	0.5479
				±	0.03	0.05	0.04									
				M5	0.06	0.06	0.09	-0.11	26	0.9144	-0.73	26	0.4694	-0.62	26	0.5422
				±	0.03	0.04	0.04									
				Mean	6.8	9.2	9									
				Score	0	2	0									

Table 9
Bottlebrush squirreltail Emerged (BSC group significance within treatments)

	contrast		estimate	SE	DF	z.ratio	p-value	
BC)	M2	M1	0.02	0.7	NA	0.03	1	
	M3	M1	0.82	0.63	NA	1.3	0.6899	
	M3	M2	0.8	0.63	NA	1.27	0.708	
	M4	M1	1.1	0.61	NA	1.79	0.3793	
	M4	M2	1.08	0.61	NA	1.76	0.396	
	M4	M3	0.28	0.53	NA	0.52	0.985	
	M5	M1	0.25	0.67	NA	0.37	0.9961	
	M5	M2	0.23	0.67	NA	0.34	0.9973	
	M5	M3	-0.57	0.6	NA	-0.95	0.8753	
	M5	M4	-0.85	0.58	NA	-1.46	0.5888	
MD)								*
	M2	M1	1.66	0.58	NA	2.85	0.0356	*
	M3	M1	0.72	0.63	NA	1.15	0.7801	
	M3	M2	-0.95	0.51	NA	-1.86	0.337	
	M4	M1	1.23	0.6	NA	2.05	0.2434	
	M4	M2	-0.44	0.47	NA	-0.92	0.8884	
	M4	M3	0.51	0.52	NA	0.97	0.8698	
	M5	M1	0.31	0.66	NA	0.48	0.9894	
	M5	M2	-1.35	0.55	NA	-2.46	0.099	*
	M5	M3	-0.41	0.59	NA	-0.69	0.9591	
	M5	M4	-0.91	0.56	NA	-1.63	0.4796	
RD)	M2	M1	0.93	0.65	NA	1.43	0.6106	
	M3	M1	1.34	0.63	NA	2.12	0.21	
	M3	M2	0.41	0.53	NA	0.78	0.937	
	M4	M1	1.57	0.62	NA	2.52	0.0871	*
	M4	M2	0.64	0.52	NA	1.23	0.7342	
	M4	M3	0.22	0.49	NA	0.46	0.9909	
	M5	M1	0.92	0.65	NA	1.4	0.625	
	M5	M2	-0.01	0.55	NA	-0.02	1	
	M5	M3	-0.42	0.53	NA	-0.8	0.9307	
	M5	M4	-0.65	0.52	NA	-1.25	0.7226	

Table 10

Bottlebrush squirreltail survival, square root transformed (BSC group significance within treatments)

	contrast		t	DF	p-value	significance
BC)	M1	M2	-0.19	26	0.8536	
	M1	M3	-1.88	26	0.07081	*
	M1	M4	-1.68	24	0.1053	!
	M1	M5	-0.17	25	0.8672	
	M2	M3	-1.73	26	0.09467	*
	M2	M4	-1.55	24	0.1348	!
	M2	M5	0	25	1	
	M3	M4	-0.08	24	0.938	
	M3	M5	1.57	25	0.1289	!
	M4	M5	1.44	26	0.1624	!
MD)	M1	M2	-2.65	26	0.01357	**
	M1	M3	-1.04	25	0.3079	
	M1	M4	-1.4	22	0.1754	!
	M1	M5	0.08	24	0.9386	
	M2	M3	1.35	26	0.1901	!
	M2	M4	0.65	23	0.5236	
	M2	M5	2.34	25	0.02733	**
	M3	M4	-0.48	25	0.6345	
	M3	M5	0.98	26	0.3363	
	M4	M5	1.33	25	0.1958	!
RD)	M1	M2	-1.15	26	0.2621	
	M1	M3	-2.62	25	0.01465	**
	M1	M4	-2.72	24	0.01193	**
	M1	M5	-0.9	22	0.3777	
	M2	M3	-1.46	26	0.1568	!
	M2	M4	-1.63	25	0.1157	!
	M2	M5	0.03	24	0.9733	
	M3	M4	-0.25	26	0.8068	
	M3	M5	1.26	25	0.2187	
	M4	M5	1.43	26	0.1653	!

*probably not much significant because numbers so low? I mean these estimates are all less than 1… and it’s not a percentage!

Table 11

Needle-and-threadgrass emergence: model significance and treatment significance within BSC groups

	Ovdisp LS means				Means and SE			***MD v BC***		***RD v. BC***		***RD v. MD***	
	Chisq	DF	p-val	BSC Group	***BC***	***MD***	***RD***	z	p-val	z	p-val	z	p-val
Interaction	20.94	8	0.0073**	M1	0.08	0.08	0.16	0.316	0.9463	1.841	0.1563	1.543	0.2710
				±	0.03	0.02	0.04						
Morphology	23.51	4	0.0001***	M2	0.04	0.56	0.42	6.877	< 0.0001*	5.744	< 0.0001*	-1.354	0.3656
				±	0.01	0.03	0.06						
Rx	26.24	2	2.0e-06***	M3	0.17	0.40	0.51	2.667	0.0209*	3.781	0.0005*	1.139	0.4897
				±	0.04	0.06	0.05						
				M4	0.18	0.42	0.39	2.778	0.0151*	2.506	0.0327*	-0.284	0.9567
				±	0.04	0.05	0.03						
				M5	0.04	0.12	0.23	2.196	0.0719*	3.929	0.0003*	1.885	0.1429
				±	0.02	0.02	0.03						
Score				***Mean***	10.2	31.6	34.2						
				Score	0	4	4						

Table 12

Needle-and-threadgrass survival: model significance and treatment significance within BSC groups

	None Ls means				Means and SE			***MD v BC***			***RD v. BC***			***RD v. MD***		
	Chisq	DF	p-val	BSC Group	***BC***	***MD***	***RD***	DF	z	p-val	DF	z	p-val	DF	z	p-val
Interaction	23.23	8	0.0031 **	M1	0.14	0.16	0.32	15	0.13	0.9913	15	1.05	0.5570	15	0.93	0.6330
				±	0.04	0.04	0.08									
Morphology	22.87	4	0.0001***	M2	0.07	0.99	0.75	15	5.39	0.0002*	15	3.99	0.0031*	15	-1.39	0.3714
				±	0.03	0.01	0.09									
Rx	22.54	2	1.279e-05 ***	M3	0.34	0.76	0.86	15	2.44	0.0671*	15	3.03	0.0217*	15	0.59	0.8280
				±	0.07	0.10	0.05									
				M4	0.36	0.75	0.76	15	2.27	0.0911*	15	2.36	0.0783*	15	0.08	0.9961
				±	0.08	0.07	0.06									
				M5	0.14	0.24	0.46	15	0.63	0.8055	15	1.94	0.1631	15	1.30	0.4144
				±	0.05	0.05	0.06									
Score				***Mean***	21	58	63									
				Score	0	3	3									

*On M1, no treatment is more beneficial, even for this species.

Table 13

Needle-and-threadrass Emerged (BSC group significance within treatments)

	contrast		estimate	SE	DF	z.ratio	p-value	
BC)	M2	M1	-0.75	0.58	NA	-1.28	0.7012	
	M3	M1	1.03	0.51	NA	2.03	0.25	
	M3	M2	1.77	0.55	NA	3.22	0.0113	**
	M4	M1	1.1	0.5	NA	2.19	0.1844	!
	M4	M2	1.85	0.55	NA	3.36	0.007	**
	M4	M3	0.08	0.47	NA	0.16	0.9999	
	M5	M1	-0.66	0.57	NA	-1.15	0.7793	
	M5	M2	0.09	0.61	NA	0.14	0.9999	
	M5	M3	-1.69	0.54	NA	-3.11	0.0163	**
	M5	M4	-1.76	0.54	NA	-3.25	0.0101	**
MD)	M2	M1	2.81	0.48	NA	5.81	< 0.0001	***
	M3	M1	2.09	0.49	NA	4.31	0.0002	***
	M3	M2	-0.72	0.45	NA	-1.61	0.4904	
	M4	M1	2.21	0.48	NA	4.56	0.0001	***
	M4	M2	-0.6	0.44	NA	-1.34	0.6653	
	M4	M3	0.12	0.45	NA	0.27	0.9988	
	M5	M1	0.39	0.51	NA	0.77	0.9396	
	M5	M2	-2.42	0.47	NA	-5.14	< 0.0001	***
	M5	M3	-1.7	0.47	NA	-3.6	0.003	***
	M5	M4	-1.82	0.47	NA	-3.86	0.0011	***
RD)	M2	M1	1.44	0.46	NA	3.1	0.0164	**
	M3	M1	1.83	0.46	NA	3.97	0.0007	***
	M3	M2	0.39	0.45	NA	0.88	0.9034	
	M4	M1	1.32	0.46	NA	2.85	0.035	**
	M4	M2	-0.12	0.45	NA	-0.27	0.9989	
	M4	M3	-0.51	0.45	NA	-1.15	0.7771	
	M5	M1	0.52	0.47	NA	1.12	0.7984	
	M5	M2	-0.92	0.45	NA	-2.02	0.2566	
	M5	M3	-1.31	0.45	NA	-2.9	0.0308	**
	M5	M4	-0.8	0.45	NA	-1.76	0.3965	

Table 14

Needle-and-threadgrass survival LSmeans (BSC group significance within treatments)

	contrast		estimate	Se	Df	t	p-value	
BC)	M2	M1	-0.71	1.7	15	-0.42	0.9927	
	M3	M1	2	1.7	15	1.18	0.7633	
	M3	M2	2.71	1.7	15	1.6	0.5199	
	M4	M1	2.21	1.7	15	1.3	0.6927	
	M4	M2	2.93	1.7	15	1.73	0.4489	
	M4	M3	0.21	1.7	15	0.13	0.9999	
	M5	M1	-0.07	1.7	15	-0.04	1	
	M5	M2	0.64	1.7	15	0.38	0.9951	
	M5	M3	-2.07	1.7	15	-1.22	0.7403	
	M5	M4	-2.29	1.7	15	-1.35	0.6683	
			0	0		0		
MD)	M2	M1	8.21	1.7	15	4.84	0.0017	***
	M3	M1	5.93	1.7	15	3.49	0.0232	**
	M3	M2	-2.29	1.7	15	-1.35	0.6683	
	M4	M1	5.86	1.7	15	3.45	0.0252	**
	M4	M2	-2.36	1.7	15	-1.39	0.6436	
	M4	M3	-0.07	1.7	15	-0.04	1	
	M5	M1	0.79	1.7	15	0.46	0.9896	
	M5	M2	-7.43	1.7	15	-4.38	0.0042	***
	M5	M3	-5.14	1.7	15	-3.03	0.0557	*
	M5	M4	-5.07	1.7	15	-2.99	0.0602	*
			0	0		0		
RD)	M2	M1	4.29	1.7	15	2.53	0.137	!
	M3	M1	5.36	1.7	15	3.16	0.044	**
	M3	M2	1.07	1.7	15	0.63	0.9676	
	M4	M1	4.43	1.7	15	2.61	0.1186	!
	M4	M2	0.14	1.7	15	0.08	1	
	M4	M3	-0.93	1.7	15	-0.55	0.9807	
	M5	M1	1.43	1.7	15	0.84	0.9133	
	M5	M2	-2.86	1.7	15	-1.68	0.4721	
	M5	M3	-3.93	1.7	15	-2.31	0.1939	!
	M5	M4	-3	1.7	15	-1.77	0.4262	

Table 15

Indian ricegrass emergence: model significance and treatment significance within BSC groups

	LSmeans			BSC	Means and SE			***MD v BC***		***RD v. BC***		***RD v. MD***	
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	z	p-val	z	p-val	z	p-val
Interaction	15.99	8	0.0425 *	M1	0.13	0.10	0.14	-0.34	0.9389	0.26	0.9625	0.60	0.8193
				±	0.04	0.03	0.04						
Morphology	14.04	4	0.0072 **	M2	0.00	0.10	0.15	3.12	0.0052*	3.31	0.0027*	0.37	0.9282
				±	0.00	0.03	0.05						
Rx	19.03	2	7.384e-05 ***	M3	0.01	0.09	0.10	2.45	0.0381*	2.78	0.0149*	0.39	0.9213
				±	0.01	0.03	0.03						
				M4	0.05	0.12	0.17	1.58	0.2529	2.58	0.0265*	1.03	0.5572
				±	0.02	0.04	0.04						
				M5	0.00	0.02	0.09	1.59	0.2493	2.95	0.0089*	2.11	0.0887*
				±	0.00	0.01	0.03						
Score				***Mean***	3.6	8.6	13						
				Score	0	2	5						

*Note, on M1 there was no benefit to drilling over ***BC***ing. ***BC*** 13%, ***MD*** 10%, ***RD***, 14%.

Table 16

Indian ricegrass survival: model significance and treatment significance within BSC groups

	Sqrt			BSC	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	6.39	8	0.6031	M1	0.23	0.19	0.28	0.25	26	0.8063	-0.52	26	0.6049	-0.80	26	0.4337
				±	0.08	0.05	0.08									
Morphology	11.29	4	0.0235 *	M2	0.01	0.20	0.26	-4.38	15	0.0005*	-3.48	14	0.0036*	-0.10	24	0.9182
				±	0.01	0.05	0.08									
Rx	16.23	2	0.0003 ***	M3	0.03	0.19	0.20	-2.32	18	0.03201*	-3.56	21	0.0019*	-0.61	25	0.547
				±	0.01	0.06	0.06									
				M4	0.09	0.24	0.34	-1.53	23	0.1385	-3.43	26	0.0020*	-1.36	25	0.1859
				±	0.03	0.08	0.07									
				M5	0.01	0.08	0.15	-2.82	17	0.0119 *	-2.83	15	0.0127*	-0.66,	23	0.5163
				±	0.01	0.03	0.06									
Score				***Mean***	7.4	18	24.6									
				Score	0	3	4									

Table 17

Indian ricegrass emerged LS means (BSC group significance within treatments)

	contrast		estimate	SE	DF	z.ratio	p-value	
BC)	M2	M1	-3.76	1.15	19	-3.26	0.0098	**
	M3	M1	-2.35	0.77	19	-3.06	0.0187	**
	M3	M2	1.42	1.25	19	1.13	0.7891	
	M4	M1	-1.09	0.64	19	-1.7	0.4342	
	M4	M2	2.68	1.18	19	2.27	0.1533	!
	M4	M3	1.26	0.8	19	1.57	0.5135	
	M5	M1	-3.76	1.15	19	-3.26	0.0098	**
	M5	M2	0	1.52	19	0	1	
	M5	M3	-1.42	1.25	19	-1.13	0.7891	
	M5	M4	-2.68	1.18	19	-2.27	0.1533	!
MD)	M2	M1	0.04	0.6	19	0.07	1	
	M3	M1	-0.24	0.62	19	-0.38	0.9954	
	M3	M2	-0.28	0.62	19	-0.46	0.9912	
	M4	M1	0.13	0.6	19	0.22	0.9995	
	M4	M2	0.09	0.6	19	0.15	0.9999	
	M4	M3	0.37	0.61	19	0.61	0.9742	
	M5	M1	-1.63	0.7	19	-2.32	0.1393	!
	M5	M2	-1.68	0.7	19	-2.38	0.12	!
	M5	M3	-1.4	0.71	19	-1.95	0.2888	
	M5	M4	-1.77	0.7	19	-2.51	0.0875	*
RD)	M2	M1	-0.09	0.59	19	-0.16	0.9999	
	M3	M1	-0.36	0.6	19	-0.6	0.975	
	M3	M2	-0.26	0.6	19	-0.44	0.9924	
	M4	M1	0.38	0.58	19	0.66	0.9654	
	M4	M2	0.47	0.58	19	0.81	0.928	
	M4	M3	0.74	0.59	19	1.26	0.7177	
	M5	M1	-0.5	0.6	19	-0.83	0.9221	
	M5	M2	-0.4	0.61	19	-0.67	0.9638	
	M5	M3	-0.14	0.61	19	-0.23	0.9994	
	M5	M4	-0.88	0.59	19	-1.48	0.5758	

Table 18

Indian ricegrass survival, square root transformed (BSC group significance within treatments)

	contrast		t	DF	p-value	
BC)	M1	M2	3.98	15	0.0012	***
	M1	M3	3	18	0.0076	**
	M1	M4	1.53	24	0.1391	!
	M1	M5	3.98	15	0.001237	***
	M2	M3	-1.49	21	0.1525	!
	M2	M4	-2.87	16	0.01091	**
	M2	M5	0	26	1	
	M3	M4	-1.64	22	0.1154	!
	M3	M5	1.49	21	0.1525	!
	M4	M5	2.87	16	0.01091	**
MD)	M1	M2	-0.18	26	0.8599	
	M1	M3	0.31	26	0.761	
	M1	M4	-0.29	25	0.7731	
	M1	M5	1.55	24	0.1338	!
	M2	M3	0.48	26	0.6334	
	M2	M4	-0.13	25	0.8961	
	M2	M5	1.8	24	0.08447	*
	M3	M4	-0.57	26	0.5763	
	M3	M5	1.11	23	0.2773	
	M4	M5	1.73	22	0.09721	*
RD)	M1	M2	0.46	25	0.6527	
	M1	M3	0.55	25	0.5902	
	M1	M4	-0.89	25	0.3834	
	M1	M5	1.49	26	0.1471	!
	M2	M3	0	23	0.9975	
	M2	M4	-1.29	23	0.2081	
	M2	M5	0.91	25	0.3735	
	M3	M4	-1.6	26	0.1225	!
	M3	M5	1.08	25	0.2883	
	M4	M5	2.55	26	0.0172	**

Table 19

Cheatgrass emergence: model significance and treatment significance within BSC groups

	LSmeans			BSC	Means and SE			***MD v BC***			***RD v. BC***			***RD v. MD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	DF	z	p-val	DF	z	p-val	DF	z	p-val
Interaction	20.22	8	0.0095**	M1	0.50	0.76	0.57	10	-0.13	0.9911	16	-0.50	0.8719	16	-0.39	0.9199
				±	0.07	0.06	0.11									
Morphology	13.41	4	0.0094 **	M2	0.73	0.89	0.89	11	1.05	0.5614	14	0.10	0.9943	12	-0.90	0.6507
				±	0.06	0.05	0.03									
Rx	15.81	2	0.0004***	M3	0.71	0.86	0.72	10	-1.34	0.4060	10	-0.29	0.9543	10	1.04	0.5724
				±	0.04	0.05	0.05									
				M4	0.64	0.96	0.77	15	3.19	0.0157*	16	1.27	0.4321	13	-2.01	0.1482
				±	0.05	0.02	0.07									
				M5	0.73	0.69	0.77	23	0.22	0.9730	18	0.07	0.9973	19	-0.15	0.9873
				±	0.07	0.05	0.05									
Score				***Mean***	66.2	83.2	74.4									
				Score	0	1	0									

BC always less than ***RD***, but not significant.

Table 20

Cheatgrass survival: model significance and treatment significance within BSC groups

	^4/ non-transformed															
	Chisq	DF	p-val	BSC Group	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
					BC	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	3.58	8	0.8929/	M1	0.73	0.86	0.68	-1.23	16	0.2377	0.36	26	0.721	1.72	16	0.1038*
	3.11	8	0.9272	±	0.10	0.04	0.10									
Morphology	7.24	4	0.1237/	M2	0.94	0.99	0.86b	-0.95	16	0.357	1.44	26	0.1630	2.93	16	0.0099*
	9.46	4	0.0505	±	0.04	0.01	0.04									
Rx	1.92	2	0.3832/	M3	0.96	0.96	0.92	-0.24	26	0.8151	0.88	21	0.3874	1.03	22	0.3146
	1.84	2	0.3984	±	0.02	0.02	0.04									
				M4	0.90	0.96	0.89	-1.10	24	0.2838	0.12	26	0.9085	1.18	23	0.2515
				±	0.04	0.03	0.05									
				M5	0.91	0.86	0.93	0.76	25	0.4549	-0.28	25	0.7844	-1.05	22	0.3048
				±	0.04	0.05	0.03									
Score				***Mean***	88.8	92.6	85.6									
				Score	0	2	0									

All cheatgrass survival was high, which likely explains why only MD significant *tests are not transformed as ^4 was inappropriate. When transformed, ***BC***1, ***MD***1, ***RD***0.

Table 21

Cheatgrass Emerged LSmeans (BSC group significance within treatments)

	contrast		estimate	SE	DF	z.ratio	p-value	significance
BC)	M2	M1	1.4	0.66	19	2.12	0.2098	
	M3	M1	1.05	0.65	19	1.62	0.4874	
	M3	M2	-0.35	0.66	19	-0.53	0.9839	
	M4	M1	0.66	0.65	19	1.02	0.8476	
	M4	M2	-0.74	0.66	19	-1.13	0.7916	
	M4	M3	-0.39	0.65	19	-0.6	0.9747	
	M5	M1	1.59	0.67	19	2.38	0.1215	!
	M5	M2	0.19	0.68	19	0.27	0.9988	
	M5	M3	0.54	0.67	19	0.81	0.9289	
	M5	M4	0.93	0.67	19	1.39	0.6314	
MD)	M2	M1	1.53	0.74	19	2.07	0.2333	
	M3	M1	0.95	0.71	19	1.34	0.6643	
	M3	M2	-0.57	0.76	19	-0.76	0.9429	
	M4	M1	2.76	0.81	19	3.41	0.0058	**
	M4	M2	1.24	0.85	19	1.46	0.5902	
	M4	M3	1.81	0.83	19	2.19	0.1851	!
	M5	M1	-0.72	0.67	19	-1.08	0.818	
	M5	M2	-2.25	0.73	19	-3.09	0.0169	**
	M5	M3	-1.67	0.7	19	-2.4	0.1141	!
	M5	M4	-3.49	0.8	19	-4.35	0.0001	***
RD)	M2	M1	2.02	0.7	19	2.88	0.0329	**
	M3	M1	0.65	0.67	19	0.96	0.8715	
	M3	M2	-1.37	0.69	19	-1.98	0.2781	
	M4	M1	1.27	0.69	19	1.84	0.3507	
	M4	M2	-0.75	0.71	19	-1.05	0.8314	
	M4	M3	0.62	0.68	19	0.91	0.8922	
	M5	M1	1.04	0.68	19	1.52	0.5482	
	M5	M2	-0.99	0.7	19	-1.41	0.6234	
	M5	M3	0.39	0.67	19	0.58	0.9787	
	M5	M4	-0.24	0.69	19	-0.34	0.997	

Table 22

Cheatgrass Survival t-test (BSC group significance within treatments)

	contrast		t.ratio	DF	p-value	
BC)	M1	M2	-1.99	18	0.0618	*
	M1	M3	-2.27	14	0.0393	**
	M1	M4	-1.6	18	0.1274	!
	M1	M5	-1.74	17	0.0991	*
	M2	M3	-0.3	19	0.7664	
	M2	M4	0.71	26	0.4811	
	M2	M5	0.49	26	0.6317	
	M3	M4	1.23	19	0.2348	
	M3	M5	0.95	19	0.3546	
	M4	M5	-0.25	26	0.8081	
MD)	M1	M2	-3.33	17	0.003965	***
	M1	M3	-2.53	22	0.01913	**
	M1	M4	-2.11	25	0.0448	**
	M1	M5	-0.11	23	0.911	
	M2	M3	0.8	22	0.43	
	M2	M4	0.84	18	0.4127	
	M2	M5	2.25	15	0.03981	**
	M3	M4	0.19	24	0.8535	
	M3	M5	1.76	18	0.09482	*
	M4	M5	1.53	21	0.1397	!
RD)	M1	M2	-1.69	18	0.1091	!
	M1	M3	-2.35	16	0.03179	**
	M1	M4	-2	18	0.06074	*
	M1	M5	-2.44	16	0.02691	**
	M2	M3	-1.18	25	0.248	
	M2	M4	-0.58	26	0.5651	
	M2	M5	-1.36	24	0.1866	!
	M3	M4	0.5	25	0.6211	
	M3	M5	-0.15	26	0.8819	
	M4	M5	-0.65	24	0.5251	

Table 23

Western yarrow emergence: model significance and treatment significance within BSC groups

	None				Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
	Chisq	DF	p-val	BSC Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	8.72	8	0.3662	M1	1.00	1.00	0.96	Data essentially constant (both 100%)			1.47	13	0.1648	1.47	13	0.1648
				±	0.00	0.00	0.02									
Morphology	2.03	4	0.73	M2	1.00	0.82	0.60	2.36	13	0.0344*	3.09	13	0.0087*	1.49	21	0.1504
				±	0.00	0.07	0.13									
Rx	2.57	2	0.2761	M3	1.00	0.99	0.95	1	13	0.3356	1.43	13	0.1768	0.91	18	0.3774
				±	0.00	0.01	0.03									
				M4	0.98	1.00	0.68	-1	13	0.3356	2.88	15	0.0117*	3.22	13	0.0067*
				±	0.02	0.00	0.10									
				M5	1.00	0.92	0.98	1.86	13	0.0851	1	13	0.3356	-1.21	19	0.2416
				±	0.00	0.04	0.02									
Score				***Mean***	99.6	94.6	83.4									
				Score	4	1	0									

Table 24

Western yarrow survival: model significance and treatment significance within BSC groups

	None			BSC	Means and SE			***BC v. MD***			***BC v. RD***			***MD v. RD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	t	DF	p-val	t	DF	p-val	t	DF	p-val
Interaction	7.20	8	0.5157	M1	0.31	0.31	0.00	0.05	26	0.9635	2.89	13	0.0127*	2.80	13	0.0150*
				±	0.11	0.11	0.00									
Morphology	18.75	4	0.0009 ***	M2	0.09	0.20	0.29	-1.14	20	0.2664	-1.80	18	0.0888*	-0.64	26	0.5287
				±	0.05	0.09	0.10									
Rx	1.16	2	0.5588	M3	0.84	0.71	0.82	1.40	24	0.1738	0.21	22	0.8382	-0.97	26	0.3398
				±	0.06	0.08	0.09									
				M4	0.81	0.38	0.46	3.15	26	0.0041*	2.46	25	0.0212*	-0.57	26	0.5745
				±	0.09	0.10	0.11									
				M5	0.62	0.79	0.49	-1.18	23	0.2494	0.89	22	0.3849	1.7	26	0.09517*
				±	0.08	0.11	0.13									
Score				***Mean***	53.4	47.8	41.2									
				Score	3	2	1									

Table 25

Western yarrow Emerged t-test (BSC group significance within treatments)

	contrast		t.ratio	DF	p-value	significance
BC)	M1	M2				
	M1	M3				
	M1	M4	1	13	0.3356	
	M1	M5				
	M2	M3				
	M2	M4	1	13	0.3356	
	M2	M5				
	M3	M4	1	13	0.3356	
	M3	M5				
	M4	M5	-1	13	0.3356	
MD)	M1	M2	2.36	13	0.0344	**
	M1	M3	1	13	0.3356	
	M1	M4				
	M1	M5	1.86	13	0.0851	*
	M2	M3	-2.13	14	0.0514	**
	M2	M4	-2.36	13	0.03442	**
	M2	M5	-1.13	21	0.2709	
	M3	M4	-1	13	0.3356	
	M3	M5	1.44	16	0.1681	!
	M4	M5	1.86	13	0.0851	*
			0			
RD)	M1	M2	2.76	14	0.0154	**
	M1	M3	0.26	24	0.7939	
	M1	M4	2.78	15	0.0143	**
	M1	M5	-0.44	26	0.6627	
	M2	M3	-2.64	15	0.0188	**
	M2	M4	-0.46	25	0.6488	
	M2	M5	-2.88	14	0.0123	**
	M3	M4	2.62	16	0.0188	**
	M3	M5	-0.64	23	0.5273	
	M4	M5	-2.94	14	0.0107	**

Table 26

Western yarrow Survival t-test (BSC group significance within treatments)

	contrast		t.ratio	DF	p-value	significance
BC)	M1	M2	1.93	18	0.0699	*
	M1	M3	-4.31	19	0.0004	***
	M1	M4	-3.52	25	0.0017	***
	M1	M5	-2.27	24	0.0323	**
	M2	M3	-10.36	25	1.44E-10	***
	M2	M4	-7.1	19	8.35E-07	***
	M2	M5	-5.79	21	9.73E-06	***
	M3	M4	0.27	22	0.7924	
	M3	M5	2.27	23	0.0330	**
	M4	M5	1.59	26	0.1243	!
MD)	M1	M2	0.76	25	0.4539	
	M1	M3	-2.96	24	0.0069	**
	M1	M4	-0.47	26	0.6403	
	M1	M5	-3.03	26	0.0055	**
	M2	M3	-4.29	26	0.0002	***
	M2	M4	-1.31	25	0.2021	
	M2	M5	-4.07	24	0.0004	***
	M3	M4	2.52	24	0.0187	**
	M3	M5	-0.57	23	0.5757	
	M4	M5	-2.64	26	0.0138	**
RD)	M1	M2	-2.83	13	0.0142	**
	M1	M3	-9.42	13	3.58E-07	***
	M1	M4	-4.25	13	0.0009	***
	M1	M5	-3.72	13	0.0026	***
	M2	M3	-4.01	25	0.0005	***
	M2	M4	-1.2	26	0.2410	
	M2	M5	-1.21	24	0.2370	
	M3	M4	2.56	25	0.0171	**
	M3	M5	2.14	23	0.0434	**
	M4	M5	-0.13	25	0.9008	

Table 27

Gooseberry globemallow emergence: model significance and treatment significance within BSC groups

	None LS means			BSC	Means and SE			***MD v BC***		***RD v. BC***		***RD v. MD***	
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	z	p-val	z	p-val	z	p-val
Interaction	20	8	0.0096 **	M1	0.11	0.10	0.03	-0.12	0.9922	-3.19	0.0040*	-3.10	0.0055*
				±	0.02	0.02	0.01						
Morphology	7.62	5	0.1788	M2	0.06	0.15	0.07	2.67	0.0206*	0.11	0.9936	-2.57	0.0275*
				±	0.01	0.03	0.02						
Rx	6.76	3	0.0799	M3	0.15	0.12	0.07	-0.92	0.6306	-2.59	0.0259*	-1.72	0.1988
				±	0.02	0.02	0.01						
				M4	0.05	0.08	0.09	1.28	0.4060	1.92	0.1331	0.67	0.7815
				±	0.01	0.01	0.02						
				M5	0.06	0.07	0.08	0.47	0.8850	1.02	0.5636	0.55	0.8440
				±	0.01	0.02	0.02						
Score				***Mean***	8.6	10.4	6.8						
				Score	2	3	0						

Table 28

Gooseberry globemallow survival: model significance and treatment significance within BSC groups

	None LS			BSC	Means and SE			***MD v BC***			***RD v. BC***			***RD v. MD***		
	Chisq	DF	p-val	Group	***BC***	***MD***	***RD***	DF	z	p-val	DF	z	p-val	DF	z	p-val
Interaction	20	8	0.0095**	M1	0.21	0.20	0.04	15	-0.19	0.9809	15	-2.34	0.0808*	15	-2.15	0.1128
				±	0.04	0.04	0.01									
Morphology	7	4	0.1199	M2	0.11	0.27	0.11	15	2.15	0.1128	15	0.00	1.0000	15	-2.15	0.1128
				±	0.03	0.05	0.03									
Rx	4	2	0.1172	M3	0.31	0.24	0.14	15	-0.94	0.6271	15	-2.15	0.1128	15	-1.22	0.4622
				±	0.05	0.04	0.03									
				M4	0.09	0.12	0.18	15	0.37	0.9261	15	1.12	0.5154	15	0.75	0.7392
				±	0.03	0.02	0.04									
				M5	0.10	0.11	0.12	15	0.19	0.9809	15	0.28	0.9576	15	0.09	0.9952
				±	0.03	0.03	0.04									
Score				***Mean***	16.4	18.8	11.8									
				Score	1	0	0									

Table 29

Gooseberry globemallow emerged LS means (BSC group significance within treatments)

	contrast		estimate	SE	DF	z-ratio	p-value	significance
BC)	M2	M1	-0.56	0.36	19	-1.56	0.5242	
	M3	M1	0.42	0.31	19	1.37	0.6481	
	M3	M2	0.98	0.34	19	2.86	0.0345	**
	M4	M1	-0.91	0.39	19	-2.36	0.1279	!
	M4	M2	-0.35	0.41	19	-0.85	0.9141	
	M4	M3	-1.33	0.37	19	-3.57	0.0033	**
	M5	M1	-0.69	0.37	19	-1.87	0.334	
	M5	M2	-0.13	0.4	19	-0.33	0.9976	
	M5	M3	-1.11	0.35	19	-3.14	0.0145	**
	M5	M4	0.22	0.42	19	0.53	0.9843	
MD)	M2	M1	0.4	0.31	19	1.29	0.7001	
	M3	M1	0.19	0.32	19	0.58	0.9785	
	M3	M2	-0.22	0.3	19	-0.71	0.9534	
	M4	M1	-0.35	0.35	19	-1.02	0.8486	
	M4	M2	-0.76	0.33	19	-2.27	0.1549	!
	M4	M3	-0.54	0.34	19	-1.58	0.5092	
	M5	M1	-0.46	0.36	19	-1.3	0.6897	
	M5	M2	-0.87	0.34	19	-2.54	0.0817	*
	M5	M3	-0.65	0.35	19	-1.86	0.3373	
	M5	M4	-0.11	0.37	19	-0.29	0.9984	
	M2	M1	0.9	0.47	19	1.94	0.2963	
	M3	M1	0.98	0.46	19	2.11	0.2162	
	M3	M2	0.07	0.38	19	0.19	0.9997	
	M4	M1	1.26	0.45	19	2.81	0.0399	**
	M4	M2	0.36	0.36	19	0.99	0.8578	
	M4	M3	0.29	0.36	19	0.81	0.9281	
	M5	M1	1.12	0.46	19	2.46	0.0994	*
	M5	M2	0.22	0.37	19	0.59	0.9764	
	M5	M3	0.15	0.36	19	0.4	0.9945	
	M5	M4	-0.14	0.35	19	-0.41	0.9942	

Table 30

Gooseberry globemallow survival LS means (BSC group significance within treatments)

	contrast		estimate	SE	DF	t.ratio	p-value	signficance
BC)	M2	M1	-1.07	0.76	15	-1.4	0.6350	
	M3	M1	0.93	0.76	15	1.22	0.7426	
	M3	M2	2	0.76	15	2.62	0.1164	!
	M4	M1	-1.21	0.76	15	-1.59	0.5249	
	M4	M2	-0.14	0.76	15	-0.19	0.9997	
	M4	M3	-2.14	0.76	15	-2.81	0.0837	*
	M5	M1	-1.14	0.76	15	-1.5	0.5797	
	M5	M2	-0.07	0.76	15	-0.09	1	
	M5	M3	-2.07	0.76	15	-2.71	0.0989	*
	M5	M4	0.07	0.76	15	0.09	1	
MD)	M2	M1	0.71	0.76	15	0.94	0.8786	
	M3	M1	0.36	0.76	15	0.47	0.9892	
	M3	M2	-0.36	0.76	15	-0.47	0.9892	
	M4	M1	-0.79	0.76	15	-1.03	0.8382	
	M4	M2	-1.5	0.76	15	-1.97	0.3282	
	M4	M3	-1.14	0.76	15	-1.5	0.5797	
	M5	M1	-0.86	0.76	15	-1.12	0.7925	
	M5	M2	-1.57	0.76	15	-2.06	0.2871	
	M5	M3	-1.21	0.76	15	-1.59	0.5249	
	M5	M4	-0.07	0.76	15	-0.09	1	
RD)	M2	M1	0.71	0.76	15	0.94	0.8786	
	M3	M1	1.07	0.76	15	1.4	0.6350	
	M3	M2	0.36	0.76	15	0.47	0.9892	
	M4	M1	1.43	0.76	15	1.87	0.3728	
	M4	M2	0.71	0.76	15	0.94	0.8786	
	M4	M3	0.36	0.76	15	0.47	0.9892	
	M5	M1	0.86	0.76	15	1.12	0.7925	
	M5	M2	0.14	0.76	15	0.19	0.9997	
	M5	M3	-0.21	0.76	15	-0.28	0.9985	
	M5	M4	-0.57	0.76	15	-0.75	0.9413	

CURRICULUM VITAE

Hilary Whitcomb
(April 2017)

CAREER OBJECTIVE:

To implement interdisciplinary approaches that increase ecosystem resilience through responsible rehabilitation and translational ecology (communication bridging) techniques.

Current Position (May 2016-present): U.S. Fish and Wildlife Service, Wildlife Biologist. Conduct biological opinion analyses in threatened or endangered species habitat in Utah, as required by Section 7 of the Endangered Species Act.

Previous Academic Experience:

PhD candidate: Ecology Center, Utah State University, 2011-present (Dissertation: "Translating post-wildfire restoration: bridging communication gaps in perceptions, innovations, and research.")

MS, Ecology Center, Utah State University, 2008-2011 (Thesis: "Temperature Increase and Invasion Effects on Great Basin Forbs: Experimental Evidence and Range Manager Perspectives.")

BA, Environmental Science, Wheaton College, 2000-2004, *Cum laude* with Departmental Honors (Thesis: "The invasive crab *Hemigrapsus sanguineus* at Mt. Hope Bay, Rhode Island.")

Relevant Work Experience:

- Data Analysis Technician 06/12 – 11/12

  Employer: SWCA Environmental Consultants

- Field Technician 06/08 – 08/08

  Employer: Utah State University Department of Watershed Sciences

- Wildlife Technician 05/07 – 06/08

  Employer: Utah Department of Natural Resources/Wildlife Resources: Great Salt Lake Ecosystem Program

Peer-reviewed book chapters and other scholarly publications:

Hruska, T., L. Huntsinger, M. Brunson, W. Li, *N*. Marshall, J. Oviedo Pro, and H.L. Whitcomb. 2016. Rangelands as social-ecological systems. Ch. 8 in D. Briske, ed. Rangeland Systems: Processes, Management and Challenges. New York: Springer. (forthcoming).

Whitcomb, H.L. 2011. Temperature Increase Effects on Sagebrush Ecosystem Forbs: Exprimental Evidence and Range Manager Perspectives. *All Graduate Theses and Dissertations*. Paper 1044. http://digitalcommons.usu.edu/etd/1044 Desert Fire, Mammal, and Plant Studies [Fact Sheet]: Social Barriers to Landscape Restoration after Fire

Rogers, H.L. 2004. "Got Crabs? The impact of the introduced crab species *Hemigrapsus sanguineus* at Mount Hope Bay in Rhode Island." Senior honors thesis, Wheaton College, Norton, MA.

Presentations at professional meetings and seminars:

Significance of biological soil crust in post-wildfire restoration: A social-ecological approach, Graduate Symposium, Utah State University, Logan, UT, April 20, 2012. "Temperature increase effects on rangeland forbs: Experimental evidence and manager perspectives", poster, 96th Ecology Society of America Annual Meeting, Austin, TX, August 7-12, 2011.

"How Will Climate Change Affect Significant Rangeland Forbs?", poster, Restoring the West Conference: Peaks to Valleys: Innovative Land Management for the Great Basin, Utah State University, Logan, UT, October 27-28, 2009.

“Biological soil crust effect on restoration grasses and forbs when range drilled, minimum till drilled, and broadcast post-fire”, poster, Restoring the West Conference: Restoration and Fire in the Interior West, Utah State University, Logan, UT, October 28-29, 2015

Awards

Wheaton College Norton, MA:

2004: Clinton V. Maccoy Prize in Ecology

2008: Julia R. Lange Fellowship

Utah State University, Logan, UT:

2008-2011 Quinney Fellowship

2014-2015 Seeley-Hinckley Scholarship