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RESEARCH ARTICLE

Successful information exchange between restoration science and practice

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The science-practice gap is often cited as a limitation to successful restoration outcomes; however, the existence of such a gap in information exchange is rarely measured. Here, we quantify the gap by focusing on common recommendations from both scientists (i.e. researchers) and managers (i.e. practitioners, land managers) on what is needed for successful restoration. We surveyed 45 managers associated with 244 invasive species (*Tamarix* spp.) removal projects across the southwestern U.S. to determine the degree to which they have utilized four strategies advocated by scientists: (1) collaborate widely, (2) monitor beyond cursory visual methods, (3) use a variety of information sources, and (4) consider project goals beyond invasive species removal. Half of these managers were also interviewed to assess managers' perceptions of the role of science in restoration. Twenty-three scientists specializing in *Tamarix*-related research in this region were also surveyed to assess how much they understood and/or shared the concerns of land managers. We found that managers were following scientists' recommendations and that managers' perceptions of the role of science in land management did not have any bearing on the management actions taken. Scientists reported being influenced by managers, and the concerns of scientists and managers were more overlapping than expected. Boundary organizations and river-wide partnerships were often cited as important in facilitating effective communication between land managers and scientists. A lack of funding for monitoring and for longer-term projects was cited by both groups as a limitation to incorporating scientists' recommendations into restoration.

Key words: boundary organizations, collaboration, information exchange, management recommendations, perception, science-practice gap

Implications for Practice

- Boundary organizations facilitate effective interaction between scientists and managers and may help to find common goals even in controversial restoration contexts.
- Managers of restoration projects do not need to value or actively seek out scientific input for scientific information to be incorporated into restoration plans if an effective network of collaboration exists for a specific restoration problem.
- A network of information sharing is more important than land managers reading scientific literature individually. Scientists should prioritize face-to-face meetings to effectively communicate their research to land managers.
- Funding and interagency conflict continue to interfere with successful collaboration between scientists and managers, even when common goals are present.

Introduction

Many ecological restoration publications in the past two decades have argued that there is an important knowledge and communication gap between scientists and managers (a.k.a., restoration practitioners and land managers; Bernhardt et al. 2007; Wohl et al. 2015; Bouska et al. 2016). The science-practice gap was one of the highest cited limitations to restoration in a survey of delegates to the Society for Ecological Restoration International Meeting conducted in 2009 (Cabin et al. 2010). Despite this, little has been done to actually quantify this gap, and what has been done is over a decade old (Bernhardt et al. 2007). Additionally, much focus has been placed on whether land managers were listening to scientists, and less so on whether scientists considered the needs and expertise of land managers. Quantifying the purported gap in knowledge and communication between these groups is an essential first step in understanding the role that transfer of knowledge has in restoration outcomes. Such an understanding is also crucial for both determining appropriate

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actions to improve communication and serving as a baseline to measure improvements in communication. In this study, we believe we are the first to quantify the knowledge gap from the perspectives of both scientists and managers working on the same system. Additionally, we provide a framework for understanding the transfer of knowledge in other restoration systems.

We investigated whether a science-practice gap in fact existed by evaluating the degree to which managers are following scientists' recommendations and vice versa. By reviewing the restoration literature between 2005 and 2018 (using the key words restoration, river or riparian, and manager or practitioner, and searching the relevant references within those papers) and reading best management practice guides provided to managers, we identified four specific recommendations from scientists and two from managers.

Of those from scientists, the first recommendation was that managers collaborate with other organizations and with researchers to widen the scope of restoration projects and create opportunities for managers to learn from one another. It was argued that this would increase the application of science-based restoration practices (Bernhardt et al. 2007; Fliervoet et al. 2013). The second was to perform systematic monitoring (rather than only visual or impressionistic assessments), because it provides comparable quantitative data regarding the health of the ecosystem, enabling comparison across projects (Shafroth et al. 2008; Suding 2011). Third, managers were advised to seek information from evidence-based sources such as peer-reviewed literature (Sutherland et al. 2004; Pullin & Knight 2005). And fourth, scientists have recommended that managers establish broad goals—particularly in the case of invasive plant removal—so that other ecological aspects, such as habitat or native vegetation, are also considered (Shafroth et al. 2008; Sher et al. 2010; Nilsson et al. 2016).

For their part, managers claim there are two key strategies needed to bridge the gap between scientists and managers. The first is for scientists to produce data and recommendations that are relevant to managers and their challenges (Gillilan et al. 2005; Esler et al. 2010). If the data collected by scientists are not relevant to the decisions managers face, then science will not be translated into actions (Cash et al. 2003; Enquist et al. 2017). Challenges include organizational factors that inhibit use of scientific information in ecological restoration, such as a particular agency focus (e.g. recreation or agriculture) that may take precedence over scientific recommendations to promote ecosystem diversity and function. For example, methods to prevent erosion can conflict with known approaches to encourage native species establishment (Gillilan et al. 2005). Managers call for scientists to be aware of these constraints when conducting their research and communicating the results. The second recommendation is that scientists incorporate managers' practical knowledge into research (Gillilan et al. 2005).

Some of the literature published by the scientific community assume that managers who are particularly receptive to scientific input and have a desire to use scientific information in their restoration planning (i.e. have an integrated relationship with science) are more likely to incorporate these four strategies advocated by the scientific community. Based on this assumption, some scientists call for improving managers' perceptions of science (in order to convince managers to follow recommendations) (Roux et al. 2006; Bernhardt et al. 2007; Stromberg et al. 2009). However, at least one study has shown that managers' perceptions of science do not influence management practices (Curtis & de Lacy 1998). In this study, we explore this discrepancy by testing whether positive attitudes toward scientific involvement in restoration incline managers to follow scientific recommendations. We will refer to this receptivity (or lack thereof) to scientific input and desire to use scientific approaches as a land manager's "perception of the role of science" in restoration.

To evaluate the actual state of the science-practice gap and information exchange, we present data from a study of invasive species removal projects across the southwestern United States. *Tamarix* spp. (tamarisk, saltcedar) is a shrubby tree that can grow in monocultures along riverways, impacting wildlife (Bateman et al. 2013; Strudley & Dalin 2013) and native plant communities (Friedman et al. 2005; Merritt & Poff 2010) through a variety of mechanisms, including elevating soil salinity (Ohrtman & Lair 2013) and wildfire (Drus 2013). Early scientific research erroneously suggested that *Tamarix* control would lead to water salvage (Chew 2013), while more recently a desire to foster native ecosystems has motivated removal (Sher 2013). As a result, *Tamarix* removal has been a common practice in river restoration projects on lands owned by a variety of agencies, including federal (e.g. Bureau of Reclamation), state (e.g. state natural resource departments), local (e.g. conservancy districts), nonprofit organizations (e.g. The Nature Conservancy), and private entities (e.g. individual landowners) since the early 1950s (Chew 2013). *Tamarix* removal projects span many agencies and institutions, some research-based while others have a management focus, making the sharing of knowledge among agencies particularly important. It should be noted that despite widespread support across agencies, *Tamarix* removal involves some controversy. Some have argued that removing *Tamarix* is a misguided idea based on xenophobia and forced on managers by scientists (Stromberg et al. 2009), while other groups advocate for retaining *Tamarix* within the ecosystem as habitat for the endangered Southwestern Willow Flycatcher and other species that have adapted to use it (Bean & Dudley 2018, Bateman et al. 2013).

Scientific publications on *Tamarix* impacts and management have increased exponentially since the 1990s (Sher 2013), in tandem with national attention and even legislation (Carlson 2013). Most of this literature has focused on documenting the negative impacts of *Tamarix* on ecosystems, removal methods, and the impact of removal, with most making specific management recommendations. Not-for-profit organizations and agencies have held numerous workshops and conferences and facilitated watershed-wide partnerships to spread this knowledge (Sher 2013). Best practice guides have been published to assist restoration efforts in this system, some with significant contributions by managers (Nissen et al. 2010; Sher et al. 2010). Thus, given the large amount of activity involving both scientists and land managers in this system, it might be expected that managers in this system would be more likely to use methods promoted by scientists and that scientists would be more sensitive to managers' concerns than has been observed in other cases. This study focuses on understanding the alignment between these two groups as a way of improving restoration outcomes both in this system and elsewhere.

We used both quantitative and qualitative data to address three questions about the potential knowledge gap between scientists and managers. First, to what degree are managers following scientific recommendations to (1) collaborate widely, (2) monitor quantitatively and systematically, (3) supplement informal information with formal information sources, and (4) consider project goals beyond invasive plant removal? Second, do the managers' perceptions of the role of science in land management affect whether those recommendations are followed, such that managers with a more integrated relationship to science are more likely to follow scientists' recommendations? And finally, are restoration scientists being influenced by managers, such as following their recommendations to conduct relevant research and incorporate experiential knowledge?

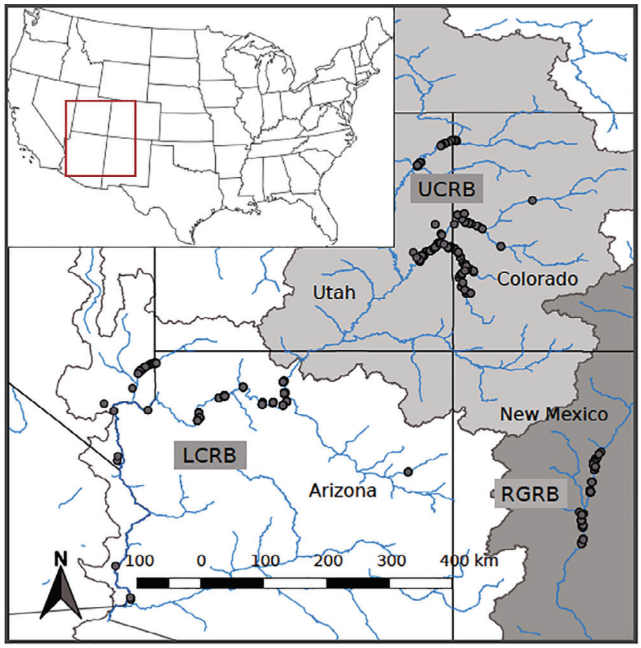

Figure 1. Map of study area. UCRB, Upper Colorado River Basin; LCRB, Lower Colorado River Basin; RGRB, Rio Grande River Basin. Points are *Tamarix* removal project sites.

Methods

In order to determine the approaches and attitudes of managers, we identified, surveyed, and interviewed the land managers responsible for 78 *Tamarix* removal projects included in a dataset of restoration outcomes representing 244 treated sites distributed across the Upper Colorado, Lower Colorado, and Rio Grande river basins in the southwestern U.S. (González et al. 2017*a*, 2017*b*; Fig. 1). The data on the Upper Colorado and Rio Grande basins are nearly comprehensive of all *Tamarix* removal in those regions since 2003. Quality, comprehensive vegetation data were not available for much of the Lower Colorado river basin, so only about 10% of existing projects in that river basin are represented in our dataset (M. McMaster, RiversEdge West, Flagstaff, AZ, U.S.A., personal communication).

The survey was created and administered online through Qualtrics (University of Denver IRB approval: #816375–8; Table S1, Supporting Information). It was developed with feedback from a subset of experienced managers and collaborators known by the authors, as well as a professional survey consultancy. The survey period was open from August 2016 to March 2017. We contacted 46 managers via email or phone; only one manager who was contacted did not complete the survey. The survey included both close-ended and open-ended questions and as such provided both qualitative and quantitative data.

In addition to the survey, all managers were invited to do an in-person or phone interview; 22 managers did so. Although this subsample was nonrandom, it was representative of the entire sample of 45 managers in terms of position, location, and organization. All but one of the interviewees also completed the survey prior to being interviewed. We used the interviews to obtain more in-depth data on land managers' perceptions of the role of science in land management and other survey responses (Table S2). The interviews were in a semistructured format that covered the topics central to our study, while still allowing respondents to raise issues we had not initially considered. Interviews took place in person at a location of the manager's choice. One interview was conducted over the phone due to scheduling difficulties. All interviews were conducted by the same interviewer (L. Clark). All interviews were recorded, transcribed, and then double-checked. All qualitative data were iteratively coded using ATLAS.ti (Markgraf et al. 2016).

Do Managers Follow Scientists' Recommendations?

We calculated percentages of managers who followed each recommendation based on the phrases that were coded according to methods presented in Saldaña (2009). For questions regarding general collaboration, collaboration for monitoring, science-specific collaboration, and collaboration for research, managers selected which groups they worked with (e.g. personnel within their agency, university scientists, local managers, etc.). For each of the four collaboration questions, the subvariables were recorded as the number of groups each manager selected. Regarding monitoring, managers selected what types of data they collected (i.e. ocular, biological, physical, and/or chemical). We tabulated each combination of methods to determine how comprehensively these managers were monitoring their *Tamarix* removal projects. For information sources, managers were asked in the survey what specific sources they found particularly useful. These open-ended responses were then qualitatively assessed (following methods in Saldaña 2014) and assigned a category: informal (e.g. face-to-face interactions, networking), formal (e.g. published sources, conference presentations), or a mix. Project goals beyond *Tamarix* removal were assessed by having managers select all of the goals they had for each project out of a possible 14 options drawn from our extensive experience of restoration project goals in the southwestern U.S. Managers' responses were then tabulated as a percentage of projects with each goal to compare the frequency of exotic plant removal as an objective to each other goal option (e.g. native plant diversity, habitat improvement, etc.). Although all sites were expected to have exotic plant removal as a goal by definition, there were five sites that were considered by the managers to be controls so *Tamarix* was not actively being removed.

Perceptions of the Role of Science in Management

To assess perceptions of the role of science in land management, we used qualitative data from interviews. There were two distinct perceptions that emerged from coding the data: the idea that practitioners and academics are very separated and do not exchange a lot of information (which we refer to as "Polarized") versus the idea that practitioners use a lot of science and scientific skills and/or work closely with scientists ("Integrated," Table S3 for associated codes). We assigned negative numeric values to the polarized codes and positive numeric values to the integrated codes and added those values together for each manager as a score along a spectrum from Polarized to Integrated. To determine if there was a relationship between perceptions of the role of science in management and whether managers follow scientists' recommendations, we used pairwise comparisons with logistic fit tests or Spearman's rho nonparametric regressions (for categorical and continuous variables, respectively) with a Bonferroni adjusted alpha.

Do Scientists Understand Land Managers?

Whether the concerns of restoration scientists and land managers reflected mutual understanding were investigated via responses from both managers and scientists. To collect data on scientists' perspectives, a short questionnaire was sent by email to 40 scientists who were identified through three different means: their name was mentioned as a valuable resource in the interviews with land managers, they contributed to the most comprehensive review book on *Tamarix* ecology and management (Sher & Quigley 2013), or they had one or more articles on *Tamarix* published in the last 10 years according to a Web of Science search. We did not include any of the authors of this paper in that sample. In Web of Science, we searched for papers with "*Tamarix* and invasive" within the categories of ecology, environmental science, and biodiversity/conservation. Of those papers, we kept any that had *Tamarix* in the abstract as the primary subject of study and excluded papers solely focusing on plant physiology. Finally, we identified current affiliations of the corresponding authors from those papers; only those affiliated with a research institution or university were included. Of the 40 scientists contacted, 22 responded. The emailed questions were designed to assess how much scientists understood and/or shared the concerns of land managers (specific wording of questions in Table S5). We used a combination of qualitative assessment and coding to compare the overlap in concerns between land managers and scientists.

Results

Do Managers Follow Scientists' Recommendations?

Overall, surveyed managers were incorporating recommendations in all four of the categories of scientists' recommendations considered here: collaboration, monitoring, information sources, and project goals. Most managers reported collaborating with one to four different groups (Fig. 2A). Only four managers said they did not collaborate at all, and one manager worked with seven different groups. Many managers agreed on the value of collaborations as represented by this quotation: "[collaboration] is huge and essential and I think it's really the way to go, especially in [restoration] because you have people that have different skill sets [and] it's just that much more beneficial if you have people that are the experts in all of those different areas coming together and coming up with the best solutions" (Author interview, 7 February 2017). The nonprofit organization RiversEdge West (previously Tamarisk Coalition, www.riversedgewest.org) was an important facilitator of collaboration for most of the interviewed managers. Since its founding in 2002, RiversEdge West has been working with managers in the southwestern U.S. on riparian restoration issues by actively connecting managers with scientists. This organization was mentioned by all but three managers (86%) in this context, that is, being crucial to project planning and obtaining funding, building partnerships with other managers upstream and downstream, and/or interpreting monitoring data.

Nearly all managers (encompassing 91% of sites) reported monitoring their projects in some way. Most monitoring was ocular (photopoints or site walk-throughs; 89%) and/or collecting biological data (vegetation transects, fish surveys, etc.; 75%). Thirty-five percent of monitoring protocols involved collecting physical data (channel cross-sections, pebble counts, etc.) and 23% collected chemical data (soil salinity, water temperature, dissolved oxygen, etc.). While ocular methods were the most common, they were usually used in conjunction with another method (83%, Fig. 2B). All managers made it clear that they understood the value of monitoring their projects but faced institutional challenges such as funding, as expressed by this manager: "Often there's money to get the project done but there's not really money to monitor or to re-treat" (Author interview, 5 December 2016).

Eighty percent of managers used formal information sources such as primary literature or conference talks, and just over half (52%) of those managers also used informal sources such as past experience or peer conversations, according to the survey responses (Fig. 2C). The importance of using mixed sources was specifically noted, as in the following: "I'm just a sponge to any sort of information out there. […] I need both [formal and informal sources]" (Author interview, 5 December 2016), "I don't know if you can weigh one [source] more than the other, it's coming from all directions" (Author interview, 29 November 2016), "repeated iterations of conversations […] is probably more valuable than any other source because all those people are reading scientific papers in different areas and they have their own networks and when we get together, we're all looking at the same system" (Author interview, 1 December

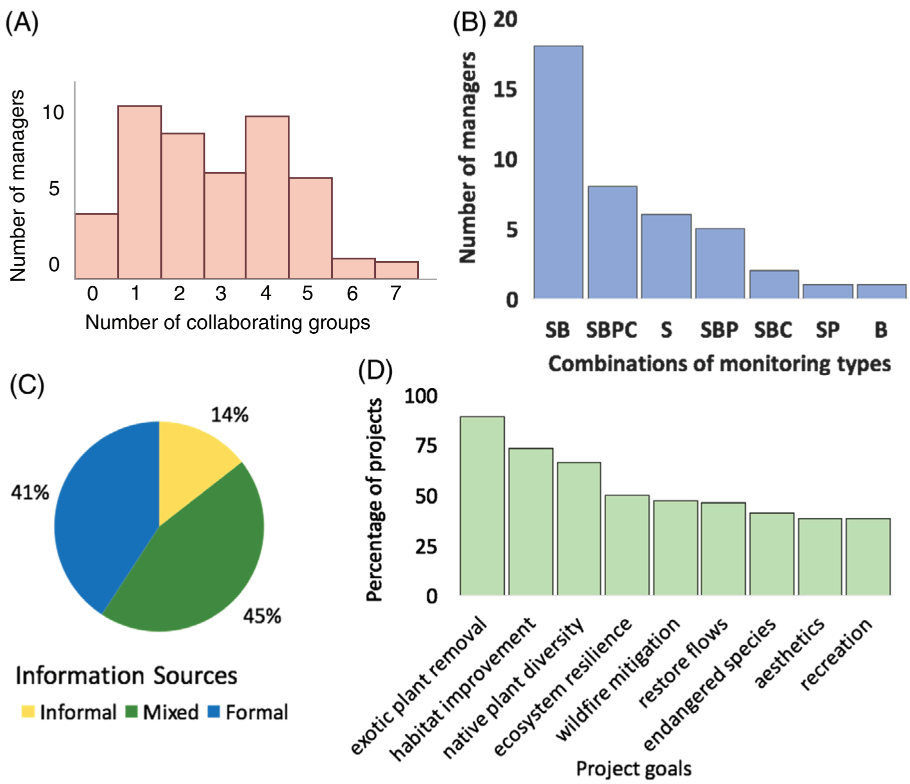

Figure 2. Distributions of each recommended practice: (A) number of general collaborations, (B) monitoring method combinations out of subjective ("S"), biological ("B"), physical ("P"), and chemical ("C"; only monitoring method type combinations associated with at least one manager are shown), (C) types of information sources used (percent of all managers that use each type), and (D) selected project goals. The following project goals are not shown as the selection rate was low (less than 20% of projects): Channel maintenance (19% of projects), water quality (19%), other (9%), forage for livestock (5%), conserve water (1%), and reduce soil salinity (1%). Exotic plant removal was not a project goal for 100% of projects as there were some projects included as controls for the vegetation study where no removal was done.

2016). RiversEdge West was specifically mentioned by 69% of managers (13% of managers had no response to the question) as a useful source of information (e.g. "[RiversEdge West's] website is pretty good as far as articles and stuff like that so it's a huge benefit, has a lot of information on it;" Author interview, 6 December 2016).

Finally, although most projects (89%) had *Tamarix* removal—and often control of another invasive plant species—as a goal, managers reported a wide variety of other goals, including those often cited in the literature by scientists, such as habitat improvement and ecosystem resilience (Fig. 2D). In some cases, a specific goal was included to satisfy a funder or landowner, but additional goals were added by the manager as well: "[fire] mitigation was [required for] funding, but with collaboration of the Dolores River Restoration Partnership and then working with our own internal staff […], they wanted to do a more holistic approach" (Author interview, 7 December 2016). In other projects, numerous goals were considered because the managers cared about the response of the entire system to the removal of *Tamarix* (e.g. "[we want] that ecological point of view, you're looking for everything," Author interview, 14 December 2016; "one of the concerns was if we start going and removing all this tamarisk, those root systems [on the high banks] are going to decay at some point and what's the bank going to do? Are the banks going to unravel? Is there going to be significant change?" Author interview, 9 December 2016).

Perceptions of the Role of Science in Management

The managers we interviewed had a wide range of perceptions of the value of scientific input in decision-making for restoration (or "role of science" in this article), from "Integrated" to "Polarized" views (see Methods section for definitions). The distribution of science perceptions as reflected in the interviews was fairly even; 48% of managers with mostly Polarized statements and 52% of managers with mostly Integrated statements (Fig. 3). However, no individual made statements exclusively within one or the other of these categories, while they may have been more integrated on some subjects and more polarized in others, when taken together, the majority of managers did not fall near either extreme of the perception spectrum.

Surprisingly, neither managers' reported perceptions nor their use of science was generally reflected in the management techniques they employed (Table S6). The few significant relationships between perception score and behavior were opposite of expectations. Seventeen percent of those with more integrated

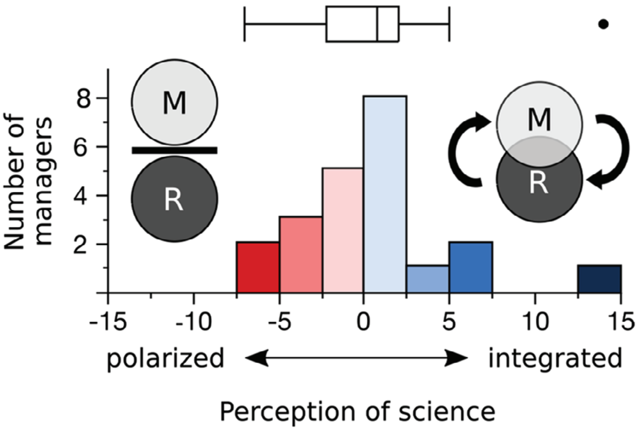

Figure 3. Distribution of managers' perception of the role of science in land management along a spectrum from Polarized to Integrated. Polarized (left, red) indicates that managers ("M," light circle) view themselves as separate from researchers ("R," dark circle) and do not exchange information. Integrated (right, blue) indicates that there is a lot of exchange of information between researchers and managers and there is not a clear distinction between the two groups. Darker colors indicate a stronger alignment to each perception. The box plot (top) shows the mean value at the center line, then each quartile out, with the dot indicating an outlier. Twenty-one managers are represented.

views (i.e. 2 managers out of 12) did not adhere to recommended management practices (by only using informal information sources or only collaborating with one group), while most of those with a more polarized view were following scientific recommendations (60% used a mix of information sources, 90% used more than just qualitative monitoring methods, and 80% collaborated with more than one group).

Do Scientists Understand Land Managers?

The data showed evidence of both understanding and misunderstanding between managers and scientists.

Aims. The two strategies suggested by land managers to bridge the knowledge gap—providing data relevant to the challenges managers face, and adjusting research to do so—were being incorporated by most scientists, at least according to their survey responses. The project aims reported by scientists generally matched those of managers (Table 1). A similar proportion of both managers and scientists (43 and 39%, respectively) were concerned by issues related to politics and logistics—including subjects such as funding, long-term commitments, and interagency conflict (see Table 1 for full list of codes). Their sentiments on funding were nearly identical, as represented by these two quotations: "with changes in funding and personnel, from the beginning we were concerned with the follow through on [maintenance and monitoring]" (Manager 143 survey), "I worry that many projects include no budget or plan to maintain cleared areas or to manage the new establishment of native vegetation" (Scientist 05).

Scientists were more than twice as likely as managers to mention concern for understanding the ecosystem as a whole, including the consequences of *Tamarix* removal ("knowledge" theme; 26 and 11%, respectively). Six scientists (27%) were concerned that managers were implementing restoration practices without considering the consequences of removal, such as secondary plant invasions (e.g. "[managers] have unrealistic goals of what *Tamarix* removal will achieve, which in the end, do not match outcomes," Scientist 21). Some managers appeared to share the concern, but not because they were not considering consequences; 29% reported feeling that they did not fully understand the potential impacts of removal, especially due to the unpredictability of the effects of weather and other human impacts (e.g. "you can somewhat predict what the end result could be, but a lot of times it never turns out [how] you're thinking it's going to," Author interview, 9 December 2016). Other managers were confident that they knew approximately what to expect because of their extensive experience in the region, like this manager: "some invasive plants have gotten worse in the riparian corridor, some have actually gotten better even without a whole lot of intervention on our part so it's a vulnerable

Table 1. Comparison table of concepts from the open-ended question: "what is your biggest concern?" Percentages represent the proportion of each group that mentioned each general concept.

Concept	*Specific codes*	*% of managers (n = 37)*	*% of scientists (n = 23)*
Data	BACI (before-after-control-impact) data, monitoring, research	8.1	8.7
Ecosystem	Beyond removal, ecological balance, ecosystem function, protect natural system, resiliency	10.8	30.4
Fire	Debris, fuel load, wildfire	13.5	4.4
Human use	Access, grazing impacts, multiple use, public overuse, recreation, safety	24.3	4.4
Hydrogeomorphology	Flooding reduced by non-native plants, hydrology, sediment, soil disturbance	18.9	26.1
Knowledge	Cause negative impacts, historic conditions, lack of knowledge, not meaningful, reckless killing, unknown effectiveness, unnecessary, unrealistic goals	10.8	26.1
Politics	Coordination, funding, interagency conflict, long-term commitment, meeting goals, overmanagement, personnel, protect investments, uncertain goals, water rights	43.2	39.1
Vegetation	Canopy cover, excessive vegetation, maintenance, native vegetation, only removal, reinvasion from upstream, remove invasive species, secondary invasion	75.7	60.9
Wildlife	Beetles, endangered species, habitat	13.5	17.4

system to invasion by aggressive non-native species" (Author interview, 1 December 2016). On the other hand, more managers than scientists were concerned with public safety ("fire") and use ("human use"). Overall, there was a great deal of overlap, and there were no themes mentioned by one group that were not repeated by the other group.

Obstacles. Overall, scientists were aware of the obstacles that managers mentioned in interviews, although there were a few differences of opinion between the two groups. Both scientists and managers talked about resource availability as an obstacle. Many managers mentioned that methods would change depending on funding (e.g. "when you're starting out you have to pick projects that you're reasonably certain are going to be successful given the resources that you have because otherwise people aren't going to want to keep giving you money," Author interview, 1 December 2016). The difficulty of obtaining long-term funding, particularly for monitoring, was echoed by 32% of scientists (e.g. "there is […] always the concern of limited resources to tackle large, complex restoration projects, particularly monitoring following restoration," Scientist 01). Managers mentioned that staff availability and time commitments were other resource-related obstacles. Time commitments made gathering formal information particularly difficult, as expressed by this manager: "I don't have time to sit here and study [the paper] and try to get into the researcher's mind to understand what that researcher is trying to show. What we want is, […] what did he do, what did he find, what worked and what didn't, and where do we go from there" (Author interview, 12 December 2016).

While there was a consensus on resource availability as an obstacle, the two groups differed in their opinions on other obstacles. Scientists were more focused on hydrological changes (e.g. dams, levees, and diversions reducing natural flooding events) than were managers (32 and 13%, respectively), voicing the concern that managers were not considering that obstacle to their projects' success (e.g. "removing the species does not modify the underpinning environmental conditions [such as temperature, water regimes, ecological disturbances]," Scientist 20; "[the main challenge is] general control over and understanding of hydrologic processes that influence the success of stream restoration," Scientist 06). However, contrary to scientists' perceptions, many managers (43% of those interviewed) were concerned about the hydrology but did not perceive it as an obstacle that could be realistically overcome. Rather, many managers talked about hydrological changes as an underlying issue that they would have to work around. None of these managers had the power or ability to influence politically charged decisions like releasing water to mimic natural flooding events or decommissioning major infrastructure. One manager mentioned that cottonwood regeneration was happening in some places but "not like you would [see] under the natural system and probably won't unless you were to remove the dam and restore that hydrograph, and that ain't gonna happen" (Author interview, 9 December 2016).

Research Change. While some scientists said that they changed their research objectives based on feedback from and collaboration with managers, many of those who said they did not still reported adjusting how they communicated their results to improve accessibility for managers. Fourteen (64%) of the scientists reported changing their research, particularly by focusing on issues relevant to managers. Four of those scientists said that they attempted to sway managers' views, such as the perceived call for a one-size-fits-all solution (e.g. "I have worked with [managers] to educate them about the uncertainties associated with various management practices and that they need to understand the context of their restoration project and avoid rules of thumb (in most cases). I have altered my research to always include applied, management-oriented conclusions and advice," Scientist 31). Half of the scientists surveyed, regardless of whether they changed their research, put a lot of value on informal interactions with managers—which contradicted the emphasis on formal information sources in the literature (e.g. "Every research project that is geared towards informing management should build in ample time to spend with managers on the ground […] simply spending time in the field, […] walking around sites with managers and discussing their question and your own lessons-learned is the most valuable communication," Scientist 06).

Discussion

Our research identifies one system where the gap between scientists and managers is much smaller than the literature suggests, as most of these managers are incorporating the four components suggested by scientists and most of these scientists are incorporating the two components suggested by managers. We suggest this may be due to the strong partnerships and particularly effective collaborative organizations in the region.

Boundary Organizations Facilitate Success in Information Exchange

One assumption that has been reported in the literature is that the attitude of land managers toward the role of science in restoration impacts the quality of decisions made by land managers (Roux et al. 2006; Bernhardt et al. 2007; Stromberg et al. 2009). Bernhardt et al. (2007) highlight the lack of reference to peer-reviewed publications by restoration practitioners as a failing in information exchange. However, the attitude of individual managers toward the role of science in restoration had no bearing on adherence to scientists' recommendations. Rather, we suggest that the many organizations and partnerships that facilitate both access to scientific information and collaborations between managers and scientists in the southwestern U.S. are responsible for such a small communication gap. Organizations that act as liaisons between science and management are termed "boundary organizations" and have been credited with improving communication between scientists and restoration practitioners in other systems (Cook et al. 2013). The organization most often named by managers is RiversEdge West (named "Tamarisk Coalition" when funded in 1999 to 2017). RiversEdge West organizes an annual conference on riparian management and *Tamarix* control with both scientists and managers in attendance and facilitates many of the watershed partnerships in the southwestern U.S. They also organize workshops for managers throughout the year, which not only facilitate technology transfer from scientists to managers, but also provide an opportunity for managers to provide feedback and information for scientists. According to online conference programs, at least 31% of the scientists surveyed in this study had given talks at one of the annual regional conferences put on by RiversEdge West.

The Dolores River Restoration Partnership was mentioned by several managers as playing a crucial role in their restoration projects. One of the most effective pieces of the DRRP was that both managers and scientists participated in all phases of the *Tamarix* removal endeavor from planning to implementation to analysis and publication (Oppenheimer et al. 2015). Thus, the project was shaped and molded by the needs of managers and the obstacles they regularly face as well as the research objectives of scientists, creating opportunities for scientists to incorporate the two components given by managers. This process has been cited recently in the restoration literature as a way to bridge the gap ("translational ecology," Enquist et al. 2017). These organizations have been involved in most restoration projects included in this study since inception and there are few projects that do not make use of one or more organizations. Without projects implemented before the creation of the organizations (RiversEdge West and the DRRP) to compare to in our database, we cannot directly test the influence of these organizations, but it is clear from both managers and scientists that they play a crucial role in *Tamarix* restoration projects. It would add to our understanding for studies in other systems to compare projects with and without the involvement of this type of organization.

However, not all partnerships are successful in bridging the gap between managers and scientists. Some managers were part of less effective watershed partnerships, particularly ones that were federally mandated. The focus in these partnerships was more on doing only what was required than on collaborative project planning. One manager expressed frustration with the situation: "I would be wanting to do more management, but the way we're organized right now, […] we're kind of relying on the [partnership] to take the lead and be helpful and supportive. I can't hardly speak up half the time […] the agendas are full of things to be done" (Author interview, 13 December 2016). Based on this, we argue that effective partnerships can make use of federal mandates to access funding, but the risk of compliance becoming a barrier to communication should be acknowledged and purposefully avoided. We believe that federal backing is not an inherent flaw in a boundary organization. To the contrary, the European Water Framework Directive was enacted to improve river restoration efforts. In Spain, this led to a National Strategy for River Restoration that helped to connect land owners, managers, and practitioners with the scientific community through conferences, workshops, and informal collaborations, and ultimately boosted the number of restoration projects in the country (González del Tánago et al. 2012). This example suggests that narrowing the communication gap by creating spaces for the two groups to interact in addition to providing formal resources often leads to better restoration outcomes.

While a detailed description of ecological outcomes of *Tamarix* removal is outside the scope of this paper, widespread *Tamarix* removal in riparian areas of the southwestern U.S. has been particularly successful (González et al. 2017*a* and references therein; Sher et al. 2018). The high level of adoption of recommendations (from and by both managers and scientists) facilitated by boundary organizations could be one explanation. A direct analysis of the relationship between management choices and the resulting plant community would further clarify if the high level of communication between scientists and managers are responsible for restoration success in this system.

A Gap Between Managers and Scientists Still Exists

The success found in the *Tamarix* removal example and the others mentioned above are encouraging, but there is still room for improvement. Scientists and managers still have decidedly different perspectives that are shaped by both cultural and institutional requirements, such as publishing papers (for scientists) and following federal mandates (for managers; Gillilan et al. 2005). Restoration scientists (particularly restoration ecologists) tend to be interested in ecosystem- or landscape-scale processes, which are also subjects that are easier to fund and publish than localized research. Land managers, on the other hand, need more practical, specific, local information, and solutions that translate into concrete actions that are especially difficult when considering global and uncertain issues such as climate change (Cabin et al. 2010). An example of this from the current study was the issue of underlying hydrology in *Tamarix* removal projects. The differing perspectives of scientists versus managers meant that they approached the issue of altered hydrology differently: while both groups mentioned its negative effect on ecosystems, managers emphasized that it is an issue beyond their capacity to change and thus requires practical work arounds. Even while some scientists acknowledged this limitation, the importance of hydrology remained a common theme. An example of bridging the gap on this particular issue would be for managers to be credited with understanding the larger ecosystem context, while scientists provide solutions and strategies for how to work with the existing flow regimes. Additionally, our result that scientists change their research to incorporate the recommendations of managers is based on self-reporting; it remains unknown if scientists are actually influenced in practice and if managers perceive this change. It is also possible that some of the recommendations by scientists for managers (e.g. comprehensive monitoring) are practices managers would have adopted regardless of recommendations. However, given that these scientific practices are not ubiquitous, even in riparian restoration (González et al. 2015), we believe it is likely that the unusually high levels of connection with scientists in this case has played a role.

Although the managers we surveyed did more monitoring than is often observed, they did not typically follow the full extent of scientific recommendations, which may appear at first as evidence of a disconnect. However, the interviews made it clear that the managers did understand its importance; the difficulty in implementation was not likely due to a lack of communication with scientists. Instead, we heard from several managers that it was difficult to find funding to monitor as comprehensively as desired. This points directly to the need for legal-regulatory mandates to monitor restoration, which would open up funding opportunities, such as in the case of the Surface Mining Control and Reclamation Act of 1977, which federally mandated monitoring the outcomes in mine restoration (Webber & Webber 1985). Similarly, state and federal mandates for riparian restoration that required a long-term monitoring component would lead to funding specifically for monitoring and would help both managers and scientists better understand the effects of restoration actions.

Regardless, the gap between managers and scientists that likely still exists in the context of *Tamarix* removal projects appears much smaller than that which the literature suggests exists between the broader scientific community in restoration and management as a whole. This disconnect is to be particularly expected when the priorities of different groups are more at odds than is found in this system.

In this study, we have shown that the widely held assumption that scientists and restoration practitioners are not communicating effectively, and therefore are not "connecting," is untrue for *Tamarix* removal across the southwestern U.S. We suspect that the unusually high degree of adoption of recommendations by both parties is a consequence of the high degree of interaction between scientists and managers in this system. This interaction has been facilitated by effective boundary organizations and partnerships. The question remains, however, whether this level of connection is unique to *Tamarix* removal projects, or if there has been an overall improvement in communication since the last large-scale assessment of the knowledge gap. This study presents contrasting results to the nationwide study of riparian restoration practitioners that found a lack of information transfer and adherence to scientific recommendations (Bernhardt et al. 2007), as well as of a global literature review of riparian restoration practices over the last 25 years that showed poor use of controls and low degree of comprehensive monitoring (González et al. 2015). Given that the recent publications calling for a narrowing of this knowledge/communication gap do not quantitatively assess the purported gap, similar studies conducted in other systems would aid in the effort to identify where there is still a large gap and also how boundary organizations contribute to restoration success.

We argue that a new emphasis should be made to facilitate effective collaborations and frequent informal interactions between the two groups, involving all relevant agencies. It appears that, in this system, boundary organizations were an effective catalyst for this communication, particularly by providing venues for interaction between scientists and practitioners. Relationship-building is crucial to successful collaborations (Roux et al. 2006), including restoration projects. Here we have presented an example of how effective this can be for incorporating scientific approaches into the practicalities of land management and vice versa. The underlying assumption is that bridging the gap is important because it should lead to improved outcomes in restoration; testing this idea will be an invaluable contribution to our understanding of the human dimension of restoration ecology.

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Online manager survey questions.
Table S2. Possible manager interview questions.
Table S3. Codes from interviews associated with each attitude toward science.
Table S4. Weighting algorithm for attitude codes.
Table S5. Questions sent to scientists via email.
Table S6. Relationship between science attitude and management decisions.

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