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URBAN STREAMS
*BRIDGES**

Closing the gap on wicked urban stream restoration problems: A framework to integrate science and community values

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Abstract: Restoring the health of urban streams has many of the characteristics of a wicked problem. Addressing a wicked problem requires managers, academics, practitioners, and community members to make negotiated tradeoffs and compromises to satisfy the values and perspectives of diverse stakeholders involved in setting restoration project goals and objectives. We conducted a gap analysis on 11 urban stream restoration projects to identify disconnections, underperformance issues, and missing processes in the project structures used to develop restoration project goals and objectives. We examined the gap analysis results to investigate whether managers appropriately identified problem statements and met stated objectives. Projects that aimed to restore overall stream health commonly fell short for various reasons, including limited stakeholder and community input and buy-in, revealing potential limitations in the breadth of objectives, values, and stakeholder perspectives and knowledge types. Projects that emphasized integrating community values and diverse knowledge types tended to meet the expected outcomes of restoring stream processes through incremental solutions. Managers implementing more holistic solutions and values-driven approaches are more likely to consider diverse viewpoints from a variety of community local institutions. Based on these and other results, we propose a conceptual framework that integrates diverse perspectives and knowledge to enhance social and ecological outcomes of urban stream restoration. The framework also emphasizes the importance of setting objectives that support incremental solutions to foster more realistic expectations amongst stakeholders.

Key words: urban streams, wicked problems, community values, social ecology, stream restoration, gap analysis, solution space, integrated knowledge, multidisciplinary approaches, social institutions, community engagement

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Streams in urban environments are unable to provide the same functions and ecosystem services typical of streams in undeveloped landscapes (Walsh et al. 2005, Kondolf and Yang 2008). Human actions continually shape hydrologic, chemical, and geomorphic conditions of urban streams that degrade the biological conditions of aquatic and riparian ecosystems (Roy et al. 2016, Van Metre et al. 2019). Restoring urban streams is a common practice to improve water quality, enhance aquatic habitat, and protect infrastructure (Kenney et al. 2012). The ecological and social challenges of restoring urban streams are complex and confounded by regulatory hurdles, funding limitations, and property right conflicts (Bernhardt and Palmer 2011). Tractable problem statements to guide restoration rarely address the collective dynamic, interdisciplinary, and multifaceted challenges that plague urban streams (Wenger et al. 2009).

Rittel and Webber (1973) introduced the concept of an unsolvable, wicked problem in where formulating the problem statement is itself highly problematic. Wicked problems are defined as being unsolvable, untamed problems (Turnbull and Hoppe 2019) and are rooted in a deep disagreement of underlying values between stakeholders (Balint et al. 2011). Approaching a wicked social problem by attempting to reduce it to a rational scientific problem fails to achieve a viable solution and often results in repetitive rounds of trying to reduce scientific uncertainty and improve public understanding of the problem (Rein and Schon 1996, Balint et al. 2011).

Restoring urban streams aligns with certain premises of a wicked problem (Rittel and Webber 1973). In practice, urban stream problems lie on a spectrum of complexity where solutions are often conceivable but difficult to implement. The set of possible solutions, or solution space, is often poorly defined for projects with complex, compounding, and often interacting components (e.g., regional climate, infrastructure, geomorphological characteristics, local ordinances, community needs, etc.). Urban design, development policies, environmental regulations, social norms, and systemic racism and classism shape contemporary urban conditions (Schell et al. 2020). For these reasons, urban stream problems are generally more complex than stream issues found in more natural environments with comparably fewer human modifications and less intense interactions among residents and the stream channel and catchment (Roy et al. 2008, Dhakal and Chevalier 2017, Qiao et al. 2018).

Gaining community support is important for the success of stream restoration efforts (Bos and Brown 2015, Smith et al. 2016, Moran et al. 2019). To successfully achieve ecological and social outcomes within a complex solution space, managers must prioritize local community engagement (Kondolf and Yang 2008, Dhakal and Chevalier 2016, Smith et al. 2016). Also, managers need to use value judgements in the decision-making process to select an appropriate solution from many options. Solution spaces defined using incomplete knowledge of community values likely prevent managers from defining reasonable restoration potential for urban streams. The inability to define restoration potential commonly leads to inconsistent success criteria between projects (Stoddard et al. 2006), piecemeal strategies (e.g., addressing individual stressors such as flooding, water quality, or erosion), or poorly defined approaches that can all contribute to ineffective interactions among stakeholders.

Including diverse community values and perspectives in the context of complex and possibly wicked urban stream restoration problems is challenging and requires that all stakeholders are willing to make compromises through negotiated tradeoffs (Scoggins et al. 2022). Social dimensions, however, can restrict how experiential and empirical knowledge moves between geographic locations and across institutions, changing how stakeholders perceive tradeoffs.

The co-authors for this Bridges article participated in the 5th Symposium on Urbanization and Stream Ecology (SUSE5), where symposium participants discussed multidisciplinary solutions to wicked problems in urban stream restoration (Scoggins et al. 2022). Following SUSE5, an international working group of scientists and engineers from academic, government, and private institutions selected a set of urban stream restoration case studies to study: 1) how managers, academics, practitioners, and community members perceive success in urban stream restoration; 2) to what extent managers and practitioners integrate community members into projects; and 3) how project planning and implementation structures contribute to success or failure.

METHODS

Urban restoration case studies

We examined diverse case studies that vary in environmental setting, scope, costs, spatial scale, and restoration goals (Table 1). When taken together, the case studies provide a modest cross section of potentially wicked problems in urban stream restoration characterized by scientific uncertainty, values disagreement, or undefined success criteria.

Using a narrative approach, case-study co-authors (i.e., a subset of this study's authors with direct knowledge of case studies) described how project goals were defined and if structured criteria and stopping rules potentially tamed the project's wickedness. Case-study co-authors also described project successes against their stated goals (i.e., not wicked) or if unintended consequences or unknowns impeded achieving stated goals that emerged in the "one-shot operation" (p. 163) of stream restoration practices typical of wicked problems (Rittel and Webber 1973). Case-study co-authors also identified shortcomings in project actions to define problems and stated whether problem definitions led to solutions that, in hindsight, missed important components or root causes of the actual problem.

Gap analysis

Survey co-authors (i.e., a subset of this study's co-authors that differed, in part, from the case-study co-authors) designed a gap analysis to describe the strengths and linkages of institutional and community involvement, and the connections of diverse types of knowledge and practices in the project. Gap analysis employs qualitative and quantitative methods to characterize why realized and intended or desired outcomes differ (Parasuraman et al. 1985). When combined with the case-study narrative, this analysis allows us to identify which project approaches were associated with success or shortcomings in the case-study projects. We also used the gap analysis to characterize gaps in project planning and implementation frameworks that restricted interdisciplinary approaches to restoration. Using this systematic approach provided opportunities to holistically examine all components and linkages (see Table 2) of project planning, design, and community involvement. The gap analysis also introduces a novel method to ask questions about how to improve restoration projects.

The survey co-authors created a perceived set of components and linkages (see Table 2 and Appendix S1 for expanded descriptions of components and linkages as presented in the survey to case-study co-authors) for interdisciplinary stream restoration projects that were translated into a survey for the case-study co-authors ($n = 11$ case studies, where the 2 phases of the Spring Run case study [Franklin Soil and Water Conservation District 2015] were considered as 2 replicates). Survey co-authors used survey responses to systematically identify potential gaps using a semi-quantitative rather than narrative approach. To guide case-study author through the gap analysis, we defined a desired outcome as a system that integrated diverse ecological and social components in urban stream restoration projects. The list of specific components and subcomponents (Table 2) and linkages among them created by the survey co-authors represented the desired system specifically to suit the needs of this study (i.e., our components and linkages are specific to the experiences conveyed through the case-study co-author narratives).

Case-study co-authors scored strengths of individual components and subcomponents (Table 2) and all pairwise linkages (i.e., a single linkage between 2 separate components or subcomponents) among all 4 main components (institutions, community, knowledge, and strategies and practices) and ≤8 institution subcomponents (Table 2) using the same scale to relativize responses. Survey respondents scored each component, subcomponent, and linkage on a scale of 1 (weak) through 5 (strong) for their case study based solely on their judgement and experiences with their specific case study. A value of 0 indicated no involvement. Case-study co-authors were instructed to interpret values of 1 and 5 as an idealistic level of potential strength that may be purely conceptual and rarely (if ever) realized in real-world projects. The component need not reach its pinnacle to be considered a 5. The survey co-authors used the analogy of an "A" grade representing ≥93% to help demonstrate the meaning for a 5 score (See for further explanation). We summarized numerical responses with Likert-scale plots of scores and network graphs of score averages (Fig. 1).

RESULTS

Among the 4 main components, case-study co-authors rated institutions the strongest and community the weakest. Institution subcomponent ratings varied in strength, but local government and consultants were generally the strongest and involved in every selected case study. Academia, nongovernmental organizations, and state government were the weakest. The number of institution types involved in each project varied from 4 (e.g., the Spring Run case study, a reach-scale backyard stream restoration project) to 8 (e.g., the Los Angeles River case study [Stein et al. 2021], a planning study in a large and highly altered watershed). Community subcomponents were ranked moderate to weak except for the Thornton Creek case study, which had strong involvement from all community subcomponents, and the South Platte River case study, which hosted various public meetings and community engagement strategies throughout the project (Fig. 1).

Respondents rated knowledge of physical and ecological science and engineering design (from the knowledge component) as moderate to strong for all case studies (Fig. 1). Respondents considered knowledge of social science and community planning to be weaker than other knowledge subcomponents. Almost half of respondents did not believe knowledge of indigenous culture was considered at all and 4 other respondents rated indigenous culture as weak (see Fig. 1).

Responses on strategies and practices followed similar patterns. Survey respondents ranked strengths of biophysical restoration strategies and practices and ecological monitoring as moderate to strong (Fig. 1), whereas respondents ranked strategies and practices referencing the community as weaker than most other subcomponents. Respondents considered all linkages between community and the other 3 main components to be weaker than all pairwise connections not including community (Fig. 2). Connections among consultants and local government were rated the strongest, and both were commonly well connected to utilities (e.g., stormwater and flood control providers). Numerous other connections were overall weak including academia to nongovernmental organizations (NGO), NGO to State Government, and Federal Government to Utility (Fig. 2).

DISCUSSION

The case-study narratives and gap analysis highlighted potential areas for improvement in developing problem statements and solution spaces. The shortcomings in problem definition, for example, seemingly prevented achieving stated goals or produced unintended consequences that

Table 1. Urban stream studies included in the gap analysis. AUS = Australia.

Study	Stream	Location	Project motivation	Stream restoration goals	Community engagement efforts	Perceived successes and shortcomings
Big Thompson Watershed Coalition 2015	Big Thompson River	Colorado, USA	Plan, design, and implement restoration measures and strategies that address adverse changes to river dynamics, aquatic habitat, and recreation following a major flood in 2013	Improve riverine functions (habitat, fish passage, floodplain connection, etc.), address water user needs, and provide recreational opportunities	Users provided input and feedback via public outreach surveys, correspondence with a coalition of citizen stakeholders, and facilitator-led community meetings	Restored river processes (e.g., floodplain connectivity and sediment continuity) and aquatic habitat. Catchment drivers not addressed, limited community engagement
Hopkins et al. 2022	Clarksburg, Little Seneca Creek	Maryland, USA	Inform impervious cover limits and stormwater management guidelines for new development within the Clarksburg special protection area	Protect water quality and biology using impervious limits, stormwater controls, and riparian buffers	Planned development, community meetings during planning, minimal engagement efforts throughout the project's lifetime	Mitigated catchment drivers related to flow regime (e.g., peak flows and runoff volumes), but water quality degraded (e.g., increase in specific conductance) and sensitive taxa were lost. Limited community engagement post-development
Sammonds and Vietz 2015	Gum Scrub Creek	Melbourne, AUS	A 100-m wide riparian corridor was required under federal legislation to support a vulnerable frog species, creating an opportunity to revitalize the waterway corridor and support other social and ecological values	Protect natural stream via buffer preservation and stream and wetland enhancements	Planned development: Developers anticipated the future residents' social values	Stream corridor protected, but catchment drivers were not addressed
City of Austin 2016a	J. J. Seabrook Reach	Texas, USA	Erosion and water-quality problems associated with upstream development spurred a collaborative approach with multiple community benefits	Restore aquatic and riparian functions by improving bank habitat and floodplain connectivity	Community engagement efforts during planning decreased over the course of the project	Structurally and ecologically successful, limited community buy-in
Walsh et al. 2015	Little Stringybark Creek	Melbourne, AUS	Research-driven project to test the real-world feasibility and effectiveness of distributed stormwater control measures for stream restoration	Restore natural flow and water-quality regimes to improve instream ecological condition in all the watershed's headwater streams	Hundreds of stormwater controls installed on private residential land required community and landowner buy-in, achieved with support from many stakeholders	Community uptake improved as engagement processes were adjusted and incentives simplified. Outcomes fell short of targets due, in part, to lack of space for structures and lack of demand for harvested stormwater

Stein et al. 2021	Los Angeles River	California, USA	Evaluate the effect of potential flow reductions on beneficial uses of the Los Angeles River and inform decisions regarding proposed wastewater change petitions	Develop tools to establish flow recommendations that balance goals for wastewater reuse, aquatic health, and recreational purposes	Facilitated public meetings (quarterly) were hosted by project leaders to gather stakeholder and community feedback on project scope and outcomes	Overall community and stakeholder buy-in on decision support tools to understand the effects of wastewater reuse on instream flows, water quality, and stream temperature. Unable to integrate the combined effects of multiple stressors on aquatic health
City of Austin 2016b	Lower Waller Creek	Texas, USA	Historic downtown flooding and the potential for economic reinvestment created an incentive to rethink the creek and corridor	Remove developed areas from floodplain, restore channel form and ecological function, and improve the look and feel in corridor	Little community engagement during floodplain restoration efforts but heavy involvement during aesthetic improvements	Massive public works effort and flood mitigation success, hydrologic and ecological components were stalled
USACE 2018	South Platte River	Colorado, USA	Create an active river corridor that restores and improves the natural habitat and function of the South Platte River and enhance the connection between the river and the community	Restore channel flows, features, and functions to enhance foraging, spawning, and protective cover habitat for indigenous fish species. Improve public recreation opportunities, connectivity, and accessibility along river	Consistent formal and informal outreach to community during the design process. Local stakeholders and nonprofit representatives provided input at public meetings during planning. Local government stakeholders participated in meetings throughout the project	Increase in recreational access and community stewardship of the river, fishery rebounded. Catchment drivers not addressed, vegetation not established limiting riparian function and habitat, secondary channels silted in
Franklin Soil and Water Conservation District 2015	Spring Run[a]	Ohio, USA	Chronic bank erosion and property loss in a residential stream threatened patios and other structures, impaired habitat, and impacted water quality	Improve stream habitat, bank stability, and water quality in a residential headwater stream	Project started with little effort to engage the community. A grassroots approach to integrate community values revived the project	Inadequate engagement led to property owner rejection of the original design and loss of grant funding. Grassroots approach revived the project, which is awaiting funding
Bakke et al. 2021	Thornton Creek	Washington, USA	Frequent flooding of residential properties and desire to improve habitat and water quality for endangered salmon	Provide flood storage in floodplain, mitigate peak flows, improve water quality, and enhance hyporheic exchange	Heavy community involvement in all project stages, highlighted by an independent film that documented project successes	Collaborative project that resulted in some water-quality improvements within restored reach

[a] This case study is presented as 2 separate rounds in the gap analysis.

Table 2. Components and subcomponents of urban stream restoration case studies assessed in the gap analysis (further explanation is provided in Appendix S1).

Component	Component description	Subcomponents
Institutions	Governmental or nongovernmental organizations that contribute to the project planning, design, or implementation through a formal or informal process	Local government State government Federal government Consultant Academia Nongovernmental organization Utility Private company
Community	Individuals, groups, or collectives that benefit from (or are affected by) the restoration work	Action groups Place-based groups Individual community leader Individual based on interest Individual based on place
Knowledge	Conceptual, historical, empirical, and theoretical representations of contextualized information and place-based wisdom (Hillman 2009) associated with the project context, design, goals, and outcomes	Physical/ecological science Community wants and needs Engineering design Restoration process Social science Policy and regulations Land-use planning Community planning Landscape architecture or structural architecture Funding procurement and management Indigenous culture relevant to project scope
Strategies and practices	Actions that occur as part of the project through all phases (design, implementation, monitoring, etc.)	Restoration: Biophysical Restoration: Social/cultural/economic/political Ecological monitoring Community survey Outreach and education Participant natural or social science training Citizen science Community planning Community empowerment and capacity building

culminated in solutions that failed to reach the full potential of community or ecological benefit. These shortcomings may have also led to inconsistent interpretations of success, which may not align with community needs and values. The gap analysis and supporting narratives demonstrated how qualitatively designated successes can fall short of the actual potential restoration outcomes possible (see Appendix S1 for further information).

In addition, the gap analysis suggested that community groups and representatives had weak roles in case-study projects and were not well connected to institutions, knowledge, and the strategies and practices employed by managers. This result aligned with themes developed during SUSE5 that focus on how communities may not be well integrated into project designs, goal setting, or evaluation (Cross and Chappell 2022, Scoggins et al. 2022). Moreover, the results contradicted qualitative outcome statements regarding community involvement (Table 1) that generally included community engagement efforts for all projects (also see Appendix S1 for information about gap analysis results unrelated to the community components).

Difficulties defining problems and identifying potential solution spaces may make problems seem intractable. Conversely, supporting knowledge transfer and interactions among stakeholders and communities may lead to better defined solution spaces. For instance, the gap analysis

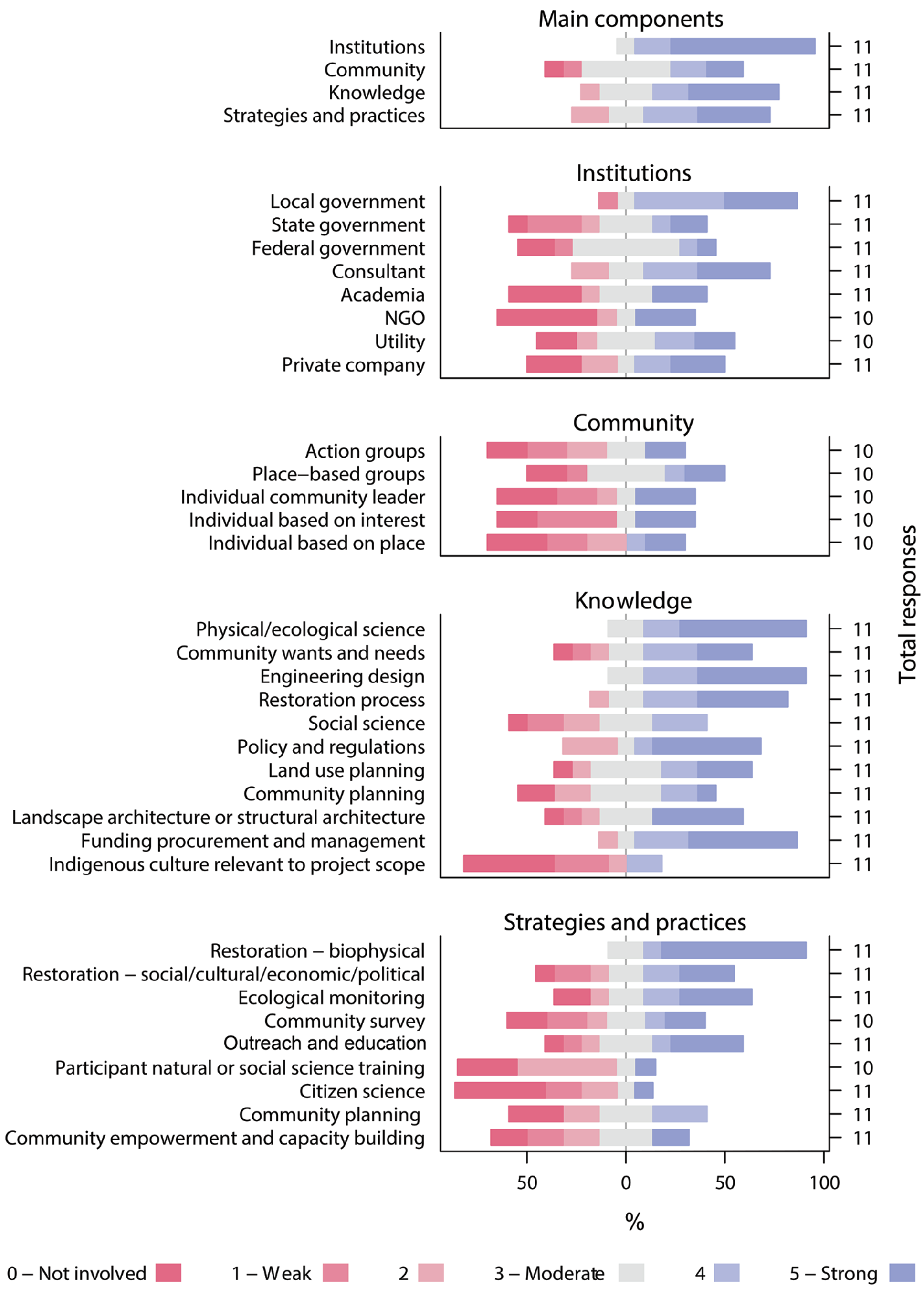

Figure 1. Case-study survey results plotted with a Likert scale showing relative strength of main components and subcomponents from 0 to 5. The % of responses with each rating is shown by bar color and horizontal position, centered on moderate (gray bars). The darkest blue bars that extend furthest to the right represent components and subcomponents with the strongest ranking. Row count totals on the right side of each diagram indicate the number of responses to each question. See Table S1 for full survey results. NGO = nongovernmental organization.

suggested that the Gum Scrub Creek (Sammonds and Vietz 2015), Little Stringybark (Walsh et al. 2015), and Big Thompson River (Big Thompson Watershed Coalition 2015) case studies each lacked inclusion of community stakeholders. A lack of broad community engagement likely limited the potential of projects to achieve community benefits in these examples where they were noted as a project goal or contributed to the omission of community-oriented goals where they were absent from these case studies. Furthermore, only 2 case studies (Thornton Creek [Bakke et al. 2021] and South Platte River [USACE 2018]) included indigenous culture when scoping and implementing the projects, emphasizing

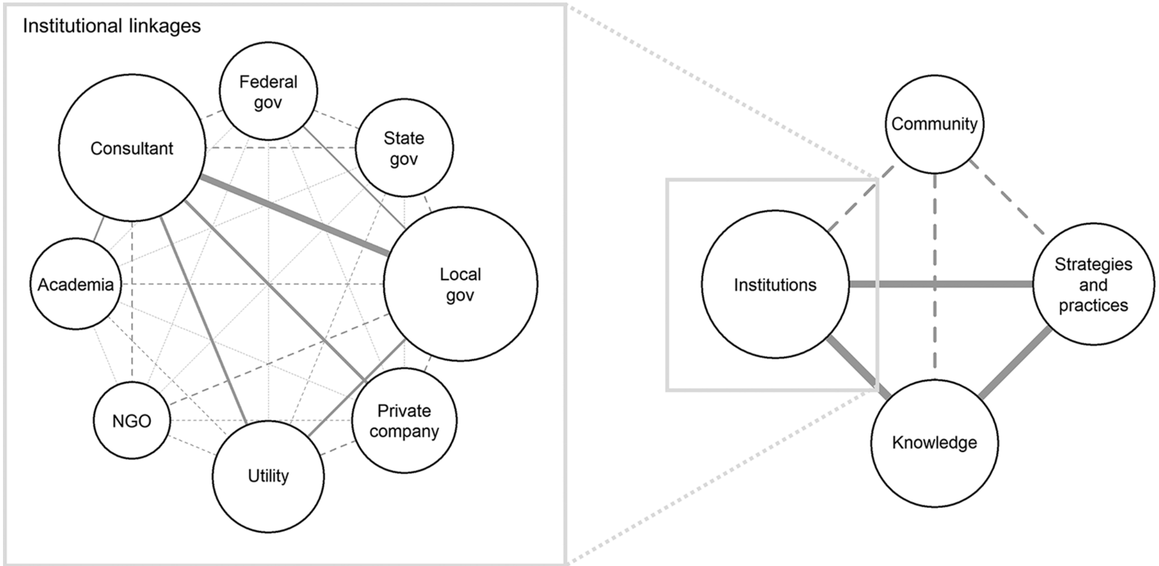

Figure 2. Network graph showing how the case-study co-authors rated strength of representation of institutions, community, knowledge, and strategies and practices and the connections between them. Strengths and connections within institution subcomponents were also analyzed. Relative strength of each component or subcomponent is shown by circle diameter, and strength of connections is shown by line weight (solid and thicker lines represent stronger connections, dashed and thinner lines represent weaker connections). Full results of the survey are presented in Table S1 and S2. Institutions, knowledge, and strategies and practices were strongly represented and interconnected while community was weakly represented and relatively unconnected to the other components. Case-study co-authors rated consultants and local government the strongest and most-linked institutions. Gov = government, NGO = nongovernmental organization.

the substantial omissions of incorporated scientific and indigenous ecological knowledge (Kimmerer 2011). Inadequate community engagement efforts for the Spring Run project suspended work to the degree of returning grant funding. A subsequent grassroots effort to integrate community values led to increased recognition of the value of community knowledge, which allowed re-implementation of the project. The narrative and gap analysis approaches suggested that ineffectively characterizing potential components of restoration actions in this case study likely contributed to a lack of engagement, which in turn may have obstructed the development of an inclusive and collaborative solution space.

We propose a conceptual framework to guide urban stream management towards problem definitions and solution spaces that encourage adaptive, collaborative, and transdisciplinary approaches to tackle complex problems and enhance societal and ecological outcomes (Fig. 3). Our framework identifies gaps in status-quo project arrangements (Fig. 3 Before) that prevent integration of diverse knowledge across fields (or clouds). Integrating all stakeholders as equal participants with strong linkages across knowledge bases and personal experiences creates a single knowledge cloud space that can employ holistic strategies and practices to address complex or wicked problems (Fig. 3 After).

The framework focuses on how project structures relate to interdisciplinary knowledge transfer necessary to address a complex problem. Specifically, communities are recognized as central holders of place-based experiential knowledge critical to developing appropriate problem statements and equitable solution spaces. Examples of centrally held place-based knowledge in our study included the Thornton Creek case study (Bakke et al. 2021), which emphasized the importance of community and institutional arrangements, and the South Platte River case study (USACE 2018), which focused on social outcomes in addition to ecological objectives. These projects demonstrate that attempting to solve a complex urban stream restoration problem requires an approach that builds capacity and collaboration within transdisciplinary stakeholder groups. The framework aligns with outcomes of other SUSE5 papers (Cross and Chappell 2022, Díaz-Pascacio et al. 2022, Scoggins et al. 2022) that demonstrated the need for approaches to set realistic expectations and consider the social context for managing urban streams in constrained urban environments.

Our analysis also highlights how a systematic approach (e.g., the gap analysis) has the potential to explicitly identify components and linkages in complex systems, although the gap analysis was most informative when performed in conjunction with the narrative-based approach. The study's findings are limited due to a small sample size of case studies and survey responses. Additionally, the selected case studies were familiar to case-study co-authors but were not a comprehensive representative sample of urban stream restoration projects. Further, case-study co-authors were highly knowledgeable but viewed their case study through a certain

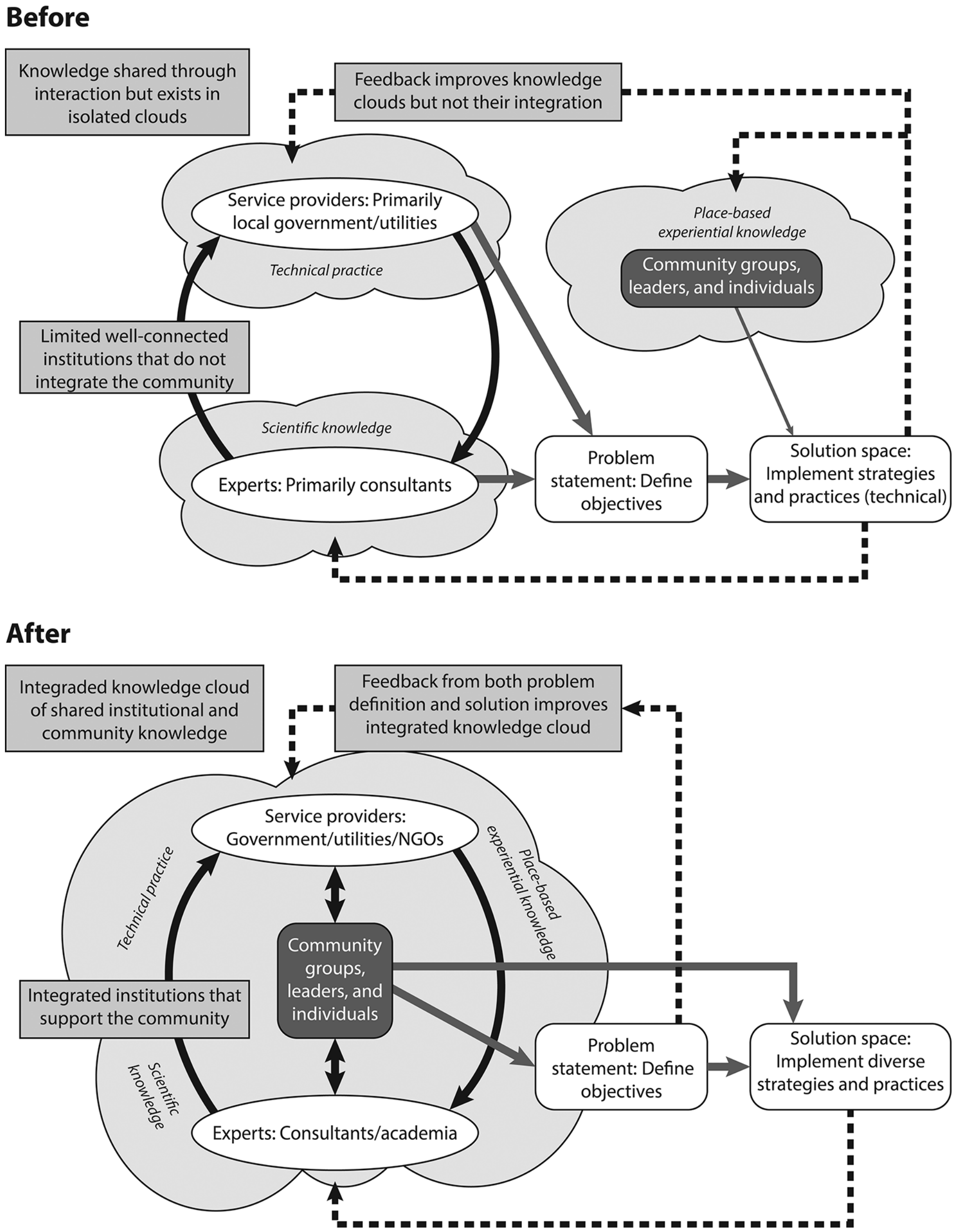

Figure 3. Before—Historical interdisciplinary knowledge is shared among groups but is not integrated to support holistic multidisciplinary approaches to restoration. Community groups are narrowly linked to the solution space. The problem statement generally excludes community input and knowledge, and the solution space is driven by how the problem is defined. After—We propose a new framework that integrates interdisciplinary knowledge, including input from community stakeholders. The problem statement integrates diverse perspectives and types of knowledge, and the solution space is driven by an appropriate problem statement and integrated community and institutional perspectives, values, and knowledge.

lens depending on their involvement. Also, the gap analysis approach to ranking linkage strength failed to capture linkage types that may vary in strength over time.

The qualitative narrative and the gap analysis need to be interpreted together to identify which project approaches may limit restoration outcomes and community involvement. For example, in Little Stringybark Creek (Walsh et al. 2015) community actions (e.g., ongoing construction of impervious surfaces, excavation of creek channels) appeared to threaten the success of the design. However, we were able to identify this component more easily with the narrative analysis. Additionally, in Gum Scrub Creek (Sammonds and Vietz 2015), identities of strong and weak institutional components were revealed by the gap analysis even though community components were not involved. Yet, the narrative described how institutional arrangements produced a solution that protected the corridor but did not address causes of stream degradation in the catchment. The gap analysis also revealed overall patterns that were not apparent in the case study narratives such as how local government and consultants commonly played a central role in defining and delivering projects.

BROADER IMPLICATIONS

Urban streams are socioecological systems and restoration work can affect the local community. Advances in urban stream restoration that achieve equitable and effective outcomes may come from project-based experimentation of new approaches in management, knowledge sharing (e.g., SUSE5), outreach, and other activities. These approaches improve integration of stakeholders and knowledge clouds to tackle complex and wicked urban stream restoration problems. By broadening the scope of stakeholder perspectives and knowledge types considered, we can uncover complexities inherent to the socioecological systems of urban streams and better develop incremental solutions to complex problems (Parsons et al. 2016). The combined narrative from SUSE5 and our gap analysis provide a foundation to tackle wicked urban stream restoration problems. Our analysis shows how systematically characterizing project attributes (e.g., prominence of local government and technical knowledge and weakness of academia and knowledge of indigenous culture) can reveal potential limitations in the solution space. Such limitations can create the appearance that solutions are impractical if not impossible. Our methods could support future urban stream restoration research with greater depth, funding, and scope than our study.

Understanding gaps in restoration systems represents a major opportunity to improve problem definitions and achieve tractable solutions. The conceptual framework we propose provides a structure to integrate diverse perspectives and knowledge and enhance social and ecological outcomes. Future work to incorporate communities likely needs leadership from local government agencies and consultants given their apparent dominant roles in projects; however, accomplishing this goal will require further defining the role community groups play in restoration projects. Integrating communities and under-represented knowledge into urban stream restoration could lead to transformative approaches to complex or wicked problems that generate equitable and effective solutions with tangible benefits to the community and ecosystems. We encourage expansion of the framework beyond a conceptual vision into a structured approach that managers can use to integrate community into restoration projects.

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Author contributions: BMM initiated this study and conceived the original idea to evaluate restoration case studies and invited colleagues from SUSE5 to collaborate on the study. RFS, KLR, BMM, and CCS designed the gap analysis to expand on the qualitative assessments and to describe the strengths of institutional and community involvement and linkages. RFS evaluated the gap analysis data and the linkages of diverse types of knowledge and practices in each project. KLR prepared the Likert plots and network graph. BMM and CCS lead the literature review. BMM, RFS, KLR, and CCS developed the conceptual framework and knowledge cloud figures.

For this study, most of our co-authors were professionally familiar with 1 or more case studies and filled out the gap analysis survey for their case study. We refer to the co-authors who submitted information on case studies as case-study co-authors to differentiate their additional contribution of the case-study information from the collaborative development of the overall outcomes of the manuscript.

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