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The development, application, and refinement of a Regenerative Development Evaluation Tool and indicators

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ABSTRACT

Ecological indicators are foundational for holistic guidance toward thriving living systems, yet existing indicators are incomplete, fragmented, and do not fully integrate living systems principles. We suggest that thriving living systems (i.e., social-ecological or complex adaptive systems) can and should be the aim of sustainability and sustainable development. Thriving living systems, also called regenerative living systems, are those in which complexity, diversity, capacity to support all life, and the potential to change to provide future options increases. Holistic ecological and sustainability indicators and evaluation tools are needed. The emerging field of regenerative development (RD) offers theoretical and practical guidance for such indicators and tools. We integrate complex adaptive systems science, ecology, sustainability, and regenerative development to construct and pilot the first iteration of a holistic sustainable development evaluation tool—the Regenerative Development Evaluation Tool—in two river restoration projects. The tool identifies RD Principles and Core Characteristics of Regenerative Living Systems that provide general guidance for thinking and decision-making. From these general indicators, place-based quantitative and qualitative indicators are constructed through a co-creative community process. Our case studies reveal factors correlated with degrees of engagement with RD and potential place-based indicators for each project. We recommend continuing the development and expansion of the RD Evaluation Tool, adding RD indicators and strategies. We also recommend developing an RD process tool that can work explicitly across scales, integrating the neighborhood, city, landscape, and regional scales since they are pivotal for sustainability efforts and manifesting thriving living systems. Finally, we recommended integrated research and practice to test and adapt RD tools and processes.

1. Introduction

Ecological indicators are necessary for supporting awareness of, decision-making for, and movement toward sustainably functioning ecosystems (Bastianoni et al., 2019; Jørgensen et al., 2015; Millennium Ecosystem Assessment, 2005; Pickett et al., 2013; WCED, 2007; Wu and Wu, 2011). Ecological indicators, however, should support sustainability by accounting for both non-human and human components of social-ecological systems (Boyle and Kay, 2008). To date, sustainability indicators tend to focus on one or more of the 'three pillars' of sustainability–environmental, social, and economic. Such an approach is reductionistic and fragmented, reflecting a mechanistic worldview at odds with how ecosystems function (Bastianoni et al., 2019; du Plessis, 2012). For example, most indicators measure some aspects of sustainability such as biodiversity, energy, water, transportation, climate, air quality, waste management, land use, poverty, and education, but largely ignore others, such as spatial considerations, stages of development and design processes, and sociocultural components such as environmental justice, values, paradigms, worldviews, and human-nature connections (Feleki et al., 2018; Huang et al., 2015; Liu, 2018; Meadows, 1999; Mori and Christodoulou, 2012; Thackara, 2006; Wu, 2010). Further, indicators often measure progress toward some 'ideal' state that may not actually exist (Bastianoni et al., 2019; du Plessis and Brandon, 2015; Kay, 2008). On their own, neither ecological nor sustainability indicators have successfully integrated necessary aspects of thriving social-ecological systems (Bastianoni et al., 2019).

We argue that thriving social-ecological systems can and should be the aim of sustainability and sustainable development efforts (du Plessis

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and Brandon, 2015). Related ecological and sustainability indicators must therefore reflect the holistic nature of social-ecological systems as complex adaptive systems, including ecological and sociocultural components and their relationships (Bastianoni et al., 2019; Boyle and Kay, 2008; du Plessis and Brandon, 2015; Holling, 2001; Innes and Booher, 2000; Ostrom, 2009; Wu, 2013). Complex adaptive systems (hereafter referred to as "living systems") are whole, dynamic, unpredictable, self-organizing, and exhibit emergent properties (Holling, 2004; Kay, 2008). When conditions are present that enable self-organization, systems can evolve beyond sustainability, or system maintenance, toward thrivability, or increasing systemic health and well-being (Boyle and Kay, 2008; Holling, 2004; Russell, 2013). Health and well-being in complex adaptive systems is defined as the condition in which complexity, diversity, capacity to support all life, and the potential to change to provide future options increases (Boyle and Kay, 2008; Holling, 2001; Mang and Reed, 2012; Presscott-Allen, 2001; Rapport, 1989). Ecological systems thinking (i.e., a holistic worldview) is foundational for supporting such a shift toward thrivability (du Plessis, 2012; Holling, 2004; Orr, 1992; Pickett et al., 2013; Russell, 2013; Smith, 2011; Wahl, 2016). Therefore, ecological indicators are foundational for holistic sustainability.

The emerging field of regenerative development (RD) offers theoretical and practical applications that can support holistic sustainability indicator and evaluation tool development. RD integrates relatively new understandings from complex adaptive systems science, ecology, quantum physics, and psychology (Mang and Reed, 2012). It posits that foundational worldviews are at the root of environmental and social challenges and intentionally adopts a holistic worldview that sees humans and nature as part of one autopoietic system (Mang, 2016). RD seeks to develop regenerative capacities in living systems that lead toward thrivability across scales, catalyzing systemic transformation (Benne and Mang, 2015; Cole, 2012; du Plessis and Brandon, 2015; du Plessis, 2012; Mang and Reed, 2012). Such systems are called "regenerative living systems." All aspects of living systems and their health—economic, social, and environmental flows, relationships, and patterns—are considered during planning, design, implementation, and monitoring in an iterative process (Mang and Reed, 2012; Mang et al., 2016). Design and development processes incorporate context-specific (i.e., place-based), dynamic ecosystem processes and humans' integral role in fostering ecosystem health. RD plans arise from iterative, deeply participatory, community-based processes that create the deep care, will, social learning, and action in inhabitants necessary for thriving living systems. They also integrate future adaptation to change (Mang and Reed, 2012; Reed, 2007). Regenerative design includes ecological design techniques and technologies (e.g., Living Buildings, Permaculture, biophilic design) that can be used in service of larger regenerative development trajectories (du Plessis and Brandon, 2015; Gibbons et al., 2018).

While RD indicators offer the potential to more holistically assess and guide projects beyond sustainability toward thrivability, their development is still in its infancy (Gibbons et al., 2018). Our paper contributes to ecological and RD indicator development and application. We first provide background on channelized river ecosystems, related indicator development to date, and the two selected case studies for the application of our assessment tool. We then develop an RD Evaluation Tool that includes RD principles and core characteristics of living systems by integrating science and practice from complex adaptive systems science, ecology, sustainability, and regenerative development. We then perform a comparative case study analysis of two river restoration projects, one in Milwaukee, Wisconsin and the other in Los Angeles, California, selected from a pool of 31 due to their integrative nature, using the tool and integrating inductive insights from the analyses. Specifically, we assess how and why the projects are regenerative by analyzing project documents and publications as well as perspectives from project stakeholders. Our findings inform further development and refinement of RD indicators and evaluation tools and elucidate potential reasons for engaging or not engaging with RD. We conclude with suggestions for holistic sustainability indicators and evaluation tools as well as future research.

1.1. Channelized river systems

We chose to pilot our RD Evaluation Tool in river restoration projects for multiple reasons. Situated within landscapes, rivers are at an important but under-investigated scale for ecological and sustainability indicators. The landscape scale connects important larger (e.g., regions and cities) and smaller (e.g., towns and neighborhoods) spatial components of living systems (Forman, 2008; Wu, 2013). Dynamic, non-channelized rivers are important ecosystems and connecting elements in landscapes, essential for both human and environmental health, well-being and sustainability (Forman, 2008). They create wildlife habitat, water and soil filtration, and flood mitigation (Gilvear et al., 2013; Terrado et al., 2016; Vermaat et al., 2016). Further, river paths, plazas, and gathering spaces provide opportunities for physical exercise and social gathering, while the positive impacts of greenspace on human well-being and happiness are well-documented (Abraham et al., 2010; Clark et al., 2007; Croucher et al., 2007; Larson et al., 2016; Pfeiffer and Cloutier, 2016; Ward Thompson et al., 2012). Thus, rivers could play an important role in catalyzing landscape and regional sustainability if guided by regenerative processes and indicators.

River restoration efforts in the United States—a response to unintended negative consequences of extensive river channelization efforts between 1930 and 1980—have been implemented in the last two decades as cities have sought to improve ecological and social conditions. Several scholars are calling for changes in how river restoration is approached, advocating for a multi-scalar perspective, the inclusion of ecologists and biologists, increased community participation, accountability and transparency in process and results, and policies that reduce anthropogenic stress on river systems (Miller and Hobbs, 2002; Perini and Sabbion, 2017; Riley, 2016). Thus, river restoration projects provide ripe ground for developing and applying a complete set of holistic sustainable development indicators that could be captured in an overarching RD evaluation tool.

1.2. Existing indicators related to regenerative development

Existing river restoration, sustainability, and ecological indicators, although incomplete for guiding holistic sustainability, could contribute to comprehensive RD indicators and evaluation tools. Existing assessment criteria and indicators for river restoration projects include water quality, water flow regimes, species diversity, population viability, redundancy, community assemblages, geomorphology, substrate composition, and connectivity. River restoration indicators have not yet integrated the sociocultural aspects of restoration, except aesthetic quality, or the potential of rivers to catalyze shifts towards sustainability in larger systems (e.g., Marttunen et al., 2019; Palmer et al., 2005; Pander and Geist, 2013; Thiele et al., 2019).

It is important to note that we tend to measure what we value and value what we measure; in other words, indicators and assessments can influence the direction of development and reflect as well as influence worldviews and values (Waltner-Toews and Kay, 2008). Sustainability indicators that measure environmental dimensions, accompanied by select economic indicators, still predominate, even though sustainability necessarily includes both environmental and sociocultural dimensions. Additionally, the linkages between dimensions are essential to sustainability but are not well captured in existing indicators (Michael et al., 2014; Verma and Raghubanshi, 2018). Further, it is unclear whether sustainability indicators are measuring the most critical aspects for increasing systemic well-being (du Plessis and Brandon, 2015; Gibbons et al., 2018; Viganò, 2013). Some of the most widely used sustainability indicators and assessment tools include the Pressure-State-Response framework (OECD, 1993), Ecological Footprint

(Wackernagel and Rees, 1996), Environmental Performance Index (Hsu et al., 2014), the United Nations' theme-based framework (United Nations Development Program, 2018), Healthy Cities Indicators (Mega and Pedersen, 1998), Life Cycle Assessment (Baumann, 2010), urban metabolism frameworks (Kennedy et al., 2011), Genuine Progress Indicator (Talberth et al., 2006), LEED (2019), BREEAM (2019) and CASBEE (2019), Living Planet Index (Loh et al., 2005), Human Development Index (United Nations Development Program, 2018), and Happy Planet Index (New Economics Foundation, 2016).

Existing ecological indicators that could be useful in an RD evaluation tool include biodiversity, protected areas, soil quality, recycling rates, green space availability and accessibility, and urban farming. Potentially useful social-ecological indicators include green jobs, equity in income, education, leisure time, and housing quality (Feleki et al., 2018). However, as discussed above, since RD represents a fundamental shift in thinking to a holistic worldview, indicators must track and guide the development of conditions that support self-organization and emergence in living systems. These conditions include the indicators just discussed and, more importantly, the relationships, flows, and emergence of system components, characteristics, processes, and structure at the focal scale, its larger context, and one scale smaller (Bastianoni et al., 2019; Boyle and Kay, 2008; du Plessis and Cole, 2011; Gibbons et al., 2018; Holling, 1973, 2004; Jørgensen et al., 2015; Wu and Loucks, 1995).

1.3. Case studies

Following, we describe the rationale for our choice of river restoration projects. Our study focuses on two river restoration cases currently underway: the Kinnickinnic River (KK River) in Milwaukee, WI, and the Los Angeles River (LA River) in Los Angeles, CA. Initially, we considered 31 river restoration cases that we identified through literature and internet searches as urban, channelized, encompassing multiple municipalities, and having restoration plans produced since 2002. We selected the KK and LA River cases because they best integrate social, economic, and ecological goals and have plans that include enough detail for our research purposes. Additionally, they have several important elements in common as well as important differences that support our research aims. First, implementation is occurring at approximately the same time—activities started in the mid-2000s and the process is expected to last decades. Second, the principal plans served as catalysts for restoration, though there are several other planning documents guiding restoration. For example, both plans aim to benefit residents through recreation, social gathering, river access, economic development, increased mobility, and environmental health improvements. Third, both rivers are fully urbanized and were channelized—the KK River in 1960, and the LA River in 1936—to control flooding and permit new development, but flood control failed and unintended negative consequences occurred. Channelization failed to fully protect residents, however, and created negative public health impacts. Finally, both projects aim to restore ecological value to the post-industrial landscape and are supported by broader water quality and management initiatives (Chase, et al., 2009). The projects are different in context, scale, and degree of engagement with systems thinking, thus providing valuable comparative data useful in testing and advancing an RD evaluation tool.

2. Methods

2.1. RD Evaluation Tool development

To construct an initial RD Evaluation Tool, we conducted an in-depth literature review to identify the major principles and characteristics of regenerative living systems and regenerative development practice. Search terms included "regenerative development," "regenerative design," "ecology," "complex adaptive systems," and "sustainability" as well as combinations of these terms. In total, we surveyed and reviewed approximately 120 scientific papers. We also participated in regenerative development and design training courses in order to gain a greater understanding of regenerative development practice and theory, beyond what is in the literature. Trainings included The Regenerative Practitioner (TRP) (Regenesis Group, 2016), LENSES (CLEAR, 2017), Gaia Education Design for Sustainability (GEDS) training (Gaia Education, 2017), and a Permaculture Design Course training (OAEC, 2018). We identified common themes and information that emerged from content analysis of literature and trainings to structure and populate the RD Evaluation Tool. Discussed in more detail in Section 3.1 and in Table 1, this structure included the overarching hierarchical framework of "RD Principles" and "Core Characteristics of Regenerative Living Systems," within which we categorized closely related information into more usable groups. The resulting tool then guided assessment and analysis of the case studies, discussed below.

2.2. Comparative case study analysis

To test our evaluation tool and understand what factors might contribute to engagement or barriers to engagement with RD, we assessed the KK and LA River projects. We used an exploratory, comparative case study approach with content analysis of planning documents and popular press articles related to the projects as well as held semi-structured and qualitative interviews with project team members (Yin, 2014). Methods included two phases: plan review and analysis, and semi-structured interviews and analysis. Our goals were to analyze how RD principles and characteristics might be applied to, or emerge from, these projects, with the goal to develop additional insights into tool development and theories for RD scholars to test. Therefore, we used both the RD Evaluation Tool and inductive content analysis for our methods.

2.2.1. Plan review and content analysis

To illuminate reasons for engagement or barriers to engagement with RD, we triangulated evidence from several sources. We reviewed formal planning sources including restoration plans, other plans (flood management, watershed, neighborhood/community/area plans, zoning overlays, design guidelines, nonprofit/academic plans), meeting minutes, government websites, local and regional newspaper and blog articles, and restoration websites. We also input multiple key words into internet search engines to find press coverage and informal planning information related to the river restoration projects. Keywords included: "Los Angeles River," "Kinnickinnic River," "restoration," "revitalization," and "plan," as well as combinations of these terms. In the case of the Kinnickinnic River, we included the project-specific terms "Milwaukee Metropolitan Sewerage District" and "Sixteenth Street Community Health Centers" to find additional sources. We reviewed the first 100 entries for each search and compiled the most relevant documents. We conducted a content analysis of the 225 most relevant texts using categories from the RD Evaluation Tool as deductive codes. To help compare the projects and elucidate potential reasons for more or less engagement with RD, we used inductive analysis to identify project goals, drivers, and catalysts; proposed or implemented activities; challenges/barriers; unique conditions in each river; potential for movement towards RD.

2.2.2. Semi-structured interviews and analysis

We triangulated our content analysis with semi-structured interviews. We identified participants via content analysis and snowball sampling, recruiting until we achieved repetition in interviewee responses (Small, 2009; Yin, 2014). In total, we interviewed 21 people, including 10 involved in the restoration of KK River, and 11 involved in the LA River restoration. Interviewees included five planners, five engineers, one landscape architect, two academic researchers, two environmental health and community engagement specialists, one urban

planning author, four nonprofit river advocates, and one economic development advocate. Several academics and river advocates also had a planning background. We fully transcribed and coded the interviews using codes as described above.

2.2.3. RD Evaluation Tool and case study analysis integration

We used common themes from our plan review, content analysis, and interviews to identify what stakeholders considered to be important aims and outcomes of river restoration projects. We used this information in conjunction with the general criteria provided by the RD Evaluation Tool (reported in Section 3.1 and Table 1) to suggest place-based indicators for the KK and LA River projects.

3. Results

3.1. RD Evaluation Tool

Our findings from the in-depth literature review and participation in regenerative development and design trainings and are summarized in the RD Evaluation Tool shown in Table 1. Although our review included many sources, we found that a smaller subset of sources articulated well the concepts represented in our larger review. Additionally, because RD is a relatively new field, uniquely regenerative concepts were articulated in an even smaller subset of sources. The sources cited in Table 1 reflect this subset. We identified three *meta*-principles in RD theory and practice (e.g., du Plessis and Brandon, 2015) that are based on current evidence from ecology, complex adaptive systems science, quantum physics, developmental change theory: wholeness, change, and relationship. Within the three *meta*-principles, we identified distinguishing features of RD, organized into seven RD Principles. First and foremost, within the *meta*-principle of wholeness, RD 1) works in whole systems, which includes the fundamental work of 2) shifting worldviews of the human components of living systems to holistic ones. This work can be done both directly and indirectly through other RD practices. With respect to the *meta*-principle of change, RD works with the dynamic nature of living systems and seeks to 3) identify and manifest potential, or essence—the core identity of a system. Manifesting potential occurs by 4) growing the regenerative capacity of whole systems—the human and non-human components' viability (ability to function), vitality (ability to thrive), and evolutionary capacity (ability to evolve). Finally, wholeness and change in living systems occur through relationships that 5) add value to larger systems (i.e., play a role that enables larger systems to manifest their potential), 6) mutualisms/guilds that enable reciprocal relationships that contribute to more vital living systems, and 7) leverage nodal points, or convergences in living systems where many flows intersect and small changes have systemic transformational effects across scales (Table 1a).

Our literature review found that all regenerative living systems exhibit similar core characteristics, and regenerative development and design incorporate these characteristics into their aims and processes. We grouped core characteristics into four categories, intended to facilitate ease of use and user learning about the systems being investigated: traits, dynamic networks, structure, and uniquely human qualities. Each category includes core characteristics that are tightly linked or related and mutually reinforcing. Traits include diversity, multifunctionality, redundancy, flexibility, and adaptability. Dynamic networks include connectedness, exchanges/flows, nodes, across-scale linkages, tight feedbacks, interdependence, and reciprocity. Structure includes modularity, holarchies, and adding value upscale. Uniquely human qualities and values include long-term thinking, reflection and learning, holistic/systems thinking and acting, collaboration, and responsibility (Table 1b). Many of these core characteristics are the same as those of resilient systems, i.e., systems capable of maintaining essentially the same identity while experiencing changing internal and external conditions (Gunderson and Holling, 2002). However, resilience is only one aspect of healthy living systems. Regenerative living systems, while resilient, exhibit characteristics that enable them to evolve to states of higher complexity and manifest new potential across scales. Additionally, in our framing of the RD Evaluation Tool, the critical element of human intentionality is included. Thus, the core characteristics of regenerative living systems include and transcend resilience.

Literature and practice indicate that an RD evaluation tool should fulfill certain structural and functional aims. Therefore, we structured the RD Evaluation Tool to mimic living systems and exemplify the RD *meta*-principles of wholeness, change, and relationship. It is hierarchical in that RD Principles must be met for a living system to be considered regenerative, and Core Characteristics enable RD. The tool is living—it can be adapted to integrate new knowledge from science and practice. It is relational—it enables users to work with the complexity of living systems without overly simplifying them (e.g., Bastianoni et al., 2019; Boyle and Kay, 2008; du Plessis and Brandon, 2015). It is developmental—it is designed to increase user understanding of processes and structure in living systems, forming the basis for understanding how they function or could function in more regenerative ways and how humans can be catalysts for whole system regeneration (e.g., Boyle and Kay, 2008; du Plessis and Brandon, 2015). Both the ecological and social dimensions of living systems and their interactions can be explicitly considered while the different domains of RD—as a process that occurs over time as well as its resulting products (e.g., infrastructure, programs, worldviews, etc.)—and their interactions can be considered simultaneously (e.g., Boyle and Kay, 2008). For instance, users might consider how the ecological and social dimensions in a living system could interact to influence levels of diversity across scale to be value-adding. They might ask how to implement processes at nodal leverage points that include a diversity of stakeholders to co-create a diversity of multifunctional, adaptable products (e.g., programs that work in ecological and social dimensions simultaneously and have multiple outcomes, such as green jobs training, citizen science initiatives, urban agriculture support and networking) that will further increase ecological and social diversity while fostering social learning, shifts towards holistic worldviews, and manifesting potential.

The RD Evaluation Tool is meant to be a general and qualitative evaluation tool to guide thinking and action. It is the first iteration of many iterations of a living tool to assess regenerative potential and guide human thinking and actions to be catalysts for shifts toward thriving living systems. It should be made more specific and expanded based on the unique context in which it is used; then, more quantitative and qualitative indicators that are meaningful for the place and its inhabitants can be integrated throughout the ecological and sociocultural dimensions as well as process and product domains. For example, biodiversity in a given place can be measured quantitatively and tracked through time as RD processes are implemented. Appropriate benchmarks for biodiversity could be established based on other biodiverse reference ecosystems (Pedersen Zari, 2012). However, to make biodiversity measurements meaningful in RD processes, they could be part of a suite of quantitative and qualitative indicators that support RD Principles, as discussed in the example above. More specific indicators could include evapotranspiration, storm water infiltration and run-off, water cycling/reuse infrastructure, soil formation and retention, phosphorous loading, educational opportunities, and nature-associated celebrations and rituals (Gaia Education, 2017; Pedersen Zari, 2018)

3.2. Case studies

Our analyses revealed that there was a greater degree of engagement with RD Principles in the KK River case than the LA River case. In LA, there were significantly more barriers that prevented engagement with RD and living systems principles, more generally. Following, we discuss in more detail our findings from applying the RD Evaluation Tool to the KK and LA River projects as well as our inductive analyses of the projects. First we share the results of applying the RD Evaluation

Table 1a
Regenerative Development Evaluation Tool construction. An in-depth literature review and participation in regenerative development and design trainings revealed themes that we categorized into Regenerative Development Principles and Core Characteristics of Regenerative Living Systems. To facilitate ease of use and user learning, we organized Regenerative Development Principles into Meta-Principles and Principles, and Core Characteristics of Regenerative Living Systems into Categories and Characteristics. Literature and practice that support these Principles and Characteristics are cited.

Regenerative Development Principles		
These principles guide thinking and action. Check all thinking and actions against RD Principles		
Meta-Principle	Principle	Supporting Literature & Practice
Wholeness	Works in whole systems (not fragments)	du Plessis and Brandon (2015), Benne and Mang (2015), Mang and Reed (2012), CLEAR (2017), Regenesis Group (2016)
	Shifts thinking towards holistic worldview	du Plessis and Brandon (2015), Mang and Reed (2012), CLEAR (2017), Regenesis Group (2016)
Change	Manifests potential in a place (potential-focused, not problem-focused)	du Plessis and Brandon (2015), Mang and Reed (2012), CLEAR (2017), Regenesis Group (2016)
	Grows Regenerative Capacity (in human and non-human components of living systems—viability, vitality, evolutionary capacity)	du Plessis and Brandon (2015), Mang and Reed (2012), CLEAR (2017), Regenesis Group (2016)
Relationships	Value-Adding: Contributes to healthier functioning/vitality of two next higher scales	Benne and Mang (2015), du Plessis and Brandon (2015), Holling (1973, 2004), Mang and Reed (2012), Walker et al. (2006), Wu and Loucks (1995), CLEAR (2017), Regenesis Group (2016)
	Mutualisms/Guilds: Creates reciprocal relationships that contribute to healthier/more vital whole	du Plessis and Brandon (2015), Mang and Reed (2012), CLEAR (2017), Regenesis Group (2016)
	Nodal leverage points: Identifies and shifts systemic leverage points to increase health and well-being	Mang and Reed (2012), Meadows (1999), CLEAR (2017), Regenesis Group (2016)
Core Characteristics of Regenerative Living Systems		
Regenerative living systems have these characteristics		
Category	Characteristic	Supporting References
Traits	Diversity (species, genetic, ecosystem, landscape, functional, response, social)	Cumming (2011), Gunderson and Holling (2002), Holling (2004), Meadows (1999), Walker and Salt (2006), Wallner et al. (1996), Walker et al. (2006), Waltner-Toews and Kay, 2008, Wu (2008), Wu and Loucks (1995)
	Multifunctionality	deGroot (2006), Lovell and Johnston (2009), Lovell and Taylor (2013), Mang and Reed (2012);
	Redundancy	Walker and Salt (2006), Wallner et al. (1996)
	Flexibility	Gunderson and Holling (2002), Wu (2008)
	Adaptability	Gunderson and Holling (2002), Meadows (1999), Wu (2008)
Dynamic Networks	Connectedness	Cumming (2011), Gunderson and Holling (2002), Mang and Reed (2012), Reed (2007), Walker and Salt (2006), Wallner et al. (1996), Wu (2008), Regenesis Group (2016)
	Exchanges/flows (materials, information, energy)	Gunderson and Holling (2002), Kay (2008), Mang and Reed (2012), Wallner et al. (1996), Wu and Loucks (1995)
	Nodes	Mang and Reed (2012), Meadows (1999), Regenesis Group (2016)
	Across-scale linkages	Benne and Mang (2015), Boyle and Kay (2008), Gunderson and Holling (2002), Mang and Reed (2012), Wu and Loucks (1995)
		TRP
	Tight feedbacks	Cummings (2011), Gunderson and Holling (2002), Kay (2008), Meadows (1999), Walker and Salt (2006);
	Interdependence	Benne and Mang (2015), Gunderson and Holling (2002), Mang and Reed (2012), Regenesis Group (2016)
	Reciprocity	Benne and Mang (2015), Mang and Reed (2012), Regenesis Group (2016)
	Being of value to larger systems	Benne and Mang (2015), Mang and Reed (2012), CLEAR (2017), OAEC (2018), Regenesis Group (2016)
Structure	Modularity	Wu (2008), Wu and Loucks (1995)
	Holarchies (heterarchies, nestedness)	Benne and Mang (2015), Cumming (2011, 2016), Gunderson and Holling (2002), Koestler, (1978), Mang and Reed (2012), Wu (2008), Kay (2008), Wu and Loucks (1995)
Uniquely human qualities and values	Long-term thinking	Boyle and Kay (2008), du Plessis and Brandon (2015), Mang et al. (2016), Meadows (1999), Regenesis Group (2016)
	Reflection, Learning	Berke (2002), Bos et al. (2013), Boyle and Kay (2008), du Plessis and Brandon (2015), Gunderson and Holling (2002), Holling (2004), Reed (2007), Reed et al. (2010), Walker et al. (2006), Walker and Salt (2006), Waltner-Toews and Kay (2008), OAEC (2018), Regenesis Group (2016)
	Holistic/Systems thinking and acting	Boyle and Kay (2008), Gunderson and Holling (2002), Mang and Reed (2012), Meadows (1999), Walker and Salt (2006), CLEAR (2017), Gaia Education (2017), OAEC (2018), Regenesis Group (2016)
	Collaboration	Bos et al. (2013), Mang and Reed (2012), Waltner-Toews and Kay (2008), CLEAR (2017), Gaia Education (2017), Regenesis Group (2016)
	Responsibility	du Plessis (2012), Meadows (1999), Reed (2007), CLEAR (2017), Gaia Education (2017), OAEC (2018), Regenesis Group (2016)

Table 1b

Regenerative Development Evaluation Tool. This tool guides communities through a holistic process of evaluating to what extent and in what ways living systems are regenerative. It may also be used to evaluate and guide development and design plans. Regenerative Development Principles and Core Characteristics of Regenerative Living systems are evaluated simultaneously in Ecological and Social dimensions of living systems as well as Process and Product domains of development and design activities. Evaluators may note system alignment &/or potential in the Dimensions and Domains columns.

Regenerative Development Principles					
These principles guide thinking and action. Check all thinking and actions against RD Principles					
Meta-Principle	Principle	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Wholeness	Works in whole systems (not fragments)				
	Shifts thinking towards holistic worldview				
Change	Manifests potential in a place (potential-focused, not problem-focused)				
	Grows Regenerative Capacity (in human and non-human components of living systems—viability, vitality, evolutionary capacity)				
Relationships	Value-Adding: Contributes to healthier functioning/vitality of two next higher scales				
	Mutualisms/Guilds: Creates reciprocal relationships that contribute to healthier/more vital whole				
	Nodal leverage points: Identifies and shifts systemic leverage points to increase health and well-being				
Core Characteristics of Regenerative Living Systems					
Regenerative living systems have these characteristics					
Category	Characteristic	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Traits	Diversity (species, genetic, ecosystem, landscape, functional, response, social)				
	Multifunctionality				
	Redundancy				
	Flexibility				
	Adaptability				
Dynamic Networks	Connectedness				
	Exchanges/flows (materials, information, energy)				
	Nodes				
	Across-scale linkages				
	Tight feedbacks				
	Interdependence				
	Reciprocity				
	Being of value to larger systems				
Structure	Modularity				
	Holarchies (heterarchies, nestedness)				
Uniquely human qualities and values	Long-term thinking				
	Reflection, Learning				
	Holistic/Systems thinking and acting				
	Collaboration				
	Responsibility				

Table 2a
Regenerative Development Evaluation of the Kinnickinnik River Restoration Project. We applied the evaluation tool to the Kinnickinnik River restoration project planning documents, popular press articles related to the project, and semi-structured and qualitative interviews with project team members. We describe in what ways principles and characteristics were demonstrated and note ideas for improvement. If they were not demonstrated, the box is left blank.

Regenerative Development Principles					
These principles guide thinking and action. Check all thinking and actions against RD Principles					
Meta-Principle	Principle	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Wholeness	Holism: Works in whole systems (not fragments)	- framework to integrate social, ecological, and health components in future projects	- framework to integrate social, ecological, and health components in future projects	- framework to integrate social, ecological, and health components in future projects	
	Shifts thinking towards holistic worldview		- river clean ups, citizen science, community engagement in design and planning, and creative place-making	- river clean ups, citizen science, community engagement in design and planning, and creative place-making	- river clean ups, citizen science
Change	Manifests potential in a place (potential-focused, not problem-focused)				
	Grows Regenerative Capacity (in human and non-human components of living systems—viability, vitality, evolutionary capacity)	- river clean ups, citizen science - pocket park: more fresh food and outdoor activity	- potential increased feeling of community ownership through choice of plans; could be more deeply co-creative - river clean ups, citizen science - construction skills program - storm water education	- river clean ups, citizen science	- river clean ups, citizen science - pocket park: more fresh food and outdoor activity - construction skills program - storm water education
Relationships	Value-Adding: Contributes to healthier functioning/vitality of two next higher scales				
	Mutualisms/Guilds: Creates reciprocal relationships that contribute to healthier/more vital whole		- new partnerships	- new partnerships	
	Nodal leverage points: Identifies and shifts systemic leverage points to increase health and well-being				
Core Characteristics of Regenerative Living Systems					
Regenerative living systems have these characteristics					
Category	Characteristic	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Traits	Diversity (species, genetic, ecosystem, landscape, functional, response, social)				
	Multifunctionality	- pocket park: more fresh food and outdoor activity	- pocket park: more fresh food and outdoor activity		- pocket park: more fresh food and outdoor activity
	Redundancy				
	Flexibility				
	Adaptability				

(*continued on next page*)

Table 2a (*continued*)

Regenerative Development Principles					
These principles guide thinking and action. Check all thinking and actions against RD Principles					
Meta-Principle	Principle	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Dynamic Networks	Connectedness				
	Exchanges/flows (materials, information, energy)	- citizen science - pocket park: more fresh food and outdoor activity	- citizen science - pocket park: more fresh food and outdoor activity - construction skills program - storm water education - local deconstruction contractors	- citizen science	- citizen science - pocket park: more fresh food and outdoor activity - construction skills program - storm water education - local deconstruction contractors
	Nodes				
	Across-scale linkages				
	Tight feedbacks		- citizen science - Technical Review Committee	- citizen science - Technical Review Committee	
	Interdependence				
	Reciprocity				
	Being of value to larger systems				
Structure	Modularity				
	Holarchies (heterarchies, nestedness)				
Uniquely human qualities and values	Long-term thinking				
	Reflection, Learning		- project team learned from and improved public participation processes, created improved framework for future projects - citizen science	- citizen science	- improved framework for future projects - citizen science
	Holistic/Systems thinking and acting		- Social-ecological systems perspective - social, health, economic, and environmental programs, but not integrated or synergistic		
	Collaboration				
	Responsibility				

Table 2b
Regenerative Development Evaluation of the Los Angeles River Restoration Project. We applied the evaluation tool to the Los Angeles River restoration project planning documents, popular press articles related to the project, and semi-structured and qualitative interviews with project team members. We describe in what ways principles and characteristics were demonstrated. If they were not demonstrated, the box is left blank.

Regenerative Development Principles					
These principles guide thinking and action. Check all thinking and actions against RD Principles					
Meta-Principle	Principle	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Wholeness	Holism: Works in whole systems (not fragments)				
	Shifts thinking towards holistic worldview		- river clean ups, citizen science, community engagement in design and planning, and creative place-making	- river clean ups, citizen science, community engagement in design and planning, and creative place-making	- river clean ups, citizen science
Change	Manifests potential in a place (potential-focused, not problem-focused)				
	Grows Regenerative Capacity (in human and non-human components of living systems—viability, vitality, evolutionary capacity)	- river clean ups, citizen science	- river clean ups, citizen science	- river clean ups, citizen science	- river clean ups, citizen science
Relationships	Value-Adding: Contributes to healthier functioning/vitality of two next higher scales				
	Mutualisms/Guilds: Creates reciprocal relationships that contribute to healthier/more vital whole		- new partnerships	- new partnerships	
	Nodal leverage points: Identifies and shifts systemic leverage points to increase health and well-being				
Core Characteristics of Regenerative Living Systems					
Regenerative living systems have these characteristics					
Category	Characteristic	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Traits	Diversity (species, genetic, ecosystem, landscape, functional, response, social)	- some projects to increase biodiversity	- diverse new partnerships		- some projects to increase biodiversity
	Multifunctionality				
	Redundancy				
	Flexibility				
	Adaptability				
Dynamic Networks	Connectedness				
	Exchanges/flows (materials, information, energy)	- some projects to support flow of water and organisms		- some projects to support flow of water and organisms	
	Nodes				
	Across-scale linkages				
	Tight feedbacks		- citizen science	- citizen science	
	Interdependence				
	Reciprocity				
	Being of value to larger systems				
Structure	Modularity				
	Holarchies (heterarchies, nestedness)				
	Long-term thinking				

(*continued on next page*)

Table 2b (*continued*)

Regenerative Development Principles					
These principles guide thinking and action. Check all thinking and actions against RD Principles					
Meta-Principle	Principle	Dimensions		Domains	
		Ecological	Sociocultural	Process	Product
Uniquely human qualities and values					
	Reflection, Learning		- river clean ups, citizen science, community engagement in design and planning, and creative place-making		
	Holistic/Systems thinking and acting		- familiarity with regenerative development and design-advocacy for watershed-wide storm water management, increased permeability, connectivity		
	Collaboration		- river clean ups, citizen science, community engagement in design and planning, and creative place-making		
	Responsibility		- river clean ups, citizen science, community engagement in design and planning, and creative place-making		

Table 3
Content analysis of project documents revealed several factors correlated with overall greater engagement with regenerative development and design in the Kinnickinnic River case study and with overall greater barriers to engagement with regenerative development and design in the Los Angeles River case study.

	Kinnickinnic River	Los Angeles River
Regenerative Development Engagement		
Regenerative Practitioners		
Familiar with Regenerative Development	✓	✓+
Living Systems Thinking		✓
Social-ecological Systems Thinking		
Regenerative Project Teams		
Visionary Leaders	✓	✓
New Partnerships	✓	✓−
Social Learning	✓	
Regenerative Programs & Projects		
Complementary Programs & Projects	✓	
Ecological, Social, and Economic Elements & Interconnections	✓	
Raising Public Awareness & Support	✓	✓−
Inclusive & Thorough Public Participation Processes	✓	✓−
Regenerative Development Barriers		
Lack of Collective Vision		
Lack of Consensus	✓	✓+
Large Living System Size		✓
Many Stakeholders/Complicated Governance		✓
Disciplinary Silos	✓	✓+
Jurisdictional Conflicts		✓
Personal Gain		✓
Conflicting Goals	✓	✓+
Institutional Constraints		✓
Implementation Challenges	✓	✓+
In-the-Box-Thinking:		
Engineering Resilience	✓	✓
Anthropocentric Focus		✓
Broader Socioeconomic Constraints		
People-Environment Dichotomy		✓
Gentrification	✓	✓+

A "✓" indicates that the listed factor was present in the case study. A "✓+" indicates the factor was present to a greater degree relative to the other case study. A "✓−" indicates that the factor was present but there were also significant barriers present. Absence of a check mark indicates the factor was absent from the case study.

Tool, grouped by RD Meta-Principles (Table 2). Then we discuss the barriers to engaging with RD that our inductive analyses revealed (Table 3).

3.2.1. Engagement with regenerative development principles and core characteristics

3.2.1.1. Meta-principle: wholeness

Principles: works in whole systems, shifts worldviews to holistic ones. Both KK and LA River participants exhibited degrees of systems and holistic thinking. Despite a lack of formal awareness of 'regenerative design and development'—only a landscape architect in the KK River case was familiar with RD due to training with John Tillman Lyle, a regenerative design pioneer—most KK River participants seemed comfortable taking and advocating for a social-ecological/living systems approach. LA River participants were more familiar with regenerative development and design than KK River participants through formal training and on-the-job learning. Many LA participants advocated for storm water management watershed-wide. There were calls to make the watershed more permeable, and to foster connectivity between the river and its tributaries. However, few seemed to think of the river as part of a living, social-ecological system. In both cases, integrated and synergistic environmental-social-economic plans,

designs, and programs were not being used to catalyze whole system health.

Social learning that could support shifts towards holistic systems thinking was a strong theme in the KK River, but was practically absent in LA. Public participation processes improved in the KK River because team members learned from past projects, each other, and project missteps about the importance of engaging the public early and often. These improvements extended to all MMSD projects, with the agency working on a framework to integrate environmental, social, ecological, and health components in future projects. There was mixed evidence, however, about cross-disciplinary learning and engagement within the KK River as a whole system. In comparison, social learning was not a common theme in LA. In fact, there appeared to be an antagonistic relationship between different river actors, some with conflicting approaches, goals, and visions. Such issues present a significant barrier to social learning, and engagement with RD.

It is not clear whether inhabitants who are not part of project teams are experiencing shifts towards systems/holistic thinking. However, both projects include programs that could facilitate such a shift, including river cleanups, citizen science, community engagement in design and planning, and creative place-making (Bence, 2014; Scauzillo, 2017; Turrentine, 2017). Most KK River interviewees believed these efforts have changed resident perspectives about the river, increasing knowledge and awareness about how the social-ecological system works as a whole. However, they expressed doubt about whether people who reside farther from the river possess that level of awareness. Although LA River interviewees were optimistic about how programs were generating enthusiasm for restoration, they worried that the thinking behind environmental degradation was not being addressed (Aleman-Zometa, 2018).

3.2.1.2. Meta-principle: change

Principles: manifests potential, grows regenerative capacity. Based on our assessment, the KK River project appears to be developing more regenerative capacity than the LA River project. KK River interviewees complemented programs that strategically address social, health, economic, and environmental aspects of community development, build capacity, and allow the community to take ownership of river restoration through involvement in plan choices. Nonprofit river advocacy organizations in both cases reported engagement with thousands of volunteers in river cleanups and citizen science activities, which could increase the viability of the system (Bence, 2014; Scauzillo, 2017; Turrentine, 2017). Participants highlighted a new multifunctional pocket park along the KK River that provides greater access to outdoor activity and fresh food, a construction skills program, bilingual education sessions on water use and stormwater runoff, and a green alley/stormwater infiltration program to increase knowledge and implementation of waterwise practices (Bence, 2015). Additionally, local contractors were required in home deconstruction processes and became advocates for KK River restoration. These initiatives could facilitate life-giving flows of food, water, information, materials, and finances through the social-ecological system.

In the LA River project, public-sector employees cited community-led designs, decision-making, participation, and creative place-making that could support the development of regenerative capacity through fostering systems thinking, responsibility, learning, and collaboration (Carruth, 2014). In comparison, LA nonprofit river advocates saw room for improvement, citing difficulties in effectively communicating within the project and processes that emphasized retention of existing power dynamics, preventing social inclusion and diversity. Some projects could support flows of organisms and water, including the half-mile Zev Yarlovsky Trail that used native plants to restore habitats that would have existed before channelization (Goldman, 2017), programs helping homeowners install green infrastructure, ordinances requiring on-site water infiltration, and floodplain widening. In both the KK and LA River cases, however, there was little evidence showing projects manifesting the potential of the rivers as holarchic living systems. The focus was primarily on identifying and fulfilling community needs and solving problems such as flooding.

3.2.1.3. Meta-principle: relationships

Principles: value-adding, creates mutualisms, shifts nodal leverage points. Both projects showed evidence of collaborations (the beginnings of guilds) to support common goals, particularly in the form of new partnerships. KK River interviewees credited the unique MMSD/SSCHC partnership with providing visionary leadership and fostering a more innovative approach to restoration due to their complementary visions, missions, and skillsets. SSCHC articulated the social and economic benefits of restoration, moving efforts more toward holism, and helped form a Technical Review Committee (TRC), moving toward implementing feedbacks. Other partners included the City, County, University of Wisconsin-Milwaukee, and the Rails-to-Trails Conservancy. These partnerships also led to complementary programs and projects within the larger restoration effort, again moving more towards holism. New partnerships in the LA River have also brought "multiple levels of expertise, history, knowledge, cultural identity, and sensitivity" to restoration, including new governance structures, thus increasing the diversity of perspectives contributing to the project. Partnerships include those between the LA River Cooperation Committee—which includes the City, County, and USACE (US Army Corp of Engineers)—the City of LA River Works Office, and non-profits (Christensen, 2018). In LA, however, there were limited discussions about leadership.

3.2.2. Barriers to engagement with regenerative development

Broader cultural, institutional, physical, and other constraints appeared to impede engagement with RD Principles in both cases, but to a greater degree in the LA River case. Barriers include: 1. lack of collective vision; 2. conflicting goals; 3. institutional constraints; 4. implementation challenges; 5. in-the-box-thinking; and 6. broader socio-economic challenges.

3.2.2.1. Lack of collective vision. Although planners and team members for the LA and KK River projects desired and worked toward generating a collective vision, challenges to consensus were present in both cases, especially in LA. There exist dozens of competing river plans from public, private, and nonprofit entities as well as conflicting visions from politicians, cities, agencies, and stakeholders. Insider/outsider dynamics were also a barrier to a collective vision in LA. They occurred, for example, when residents perceived outside interests as a threat, giving rise to gentrification concerns. In contrast, in the KK River and watershed, complementary plans serving a common vision guided river restoration. In addition, a single entity, MMSD, possessed jurisdiction over the channel and adjacent land, enabling easier implementation and coordination of projects throughout the area. However, KK River still demonstrated evidence of competing visions, such as contention about sufficient public participation processes and home removal. Improvements in public engagement processes were made, resulting in the opportunity for inhabitants to provide future input in planning and design processes.

Disciplinary siloes also impede collective vision and collaboration in both cases, particularly in LA. These issues manifest in disagreements between members of different disciplines when they collaborate sequentially instead of throughout the arc of a project. For instance, public sector employees and nonprofit river advocates held distinctly different perceptions about restoration in LA. Jurisdictional conflicts were also a major barrier to consensus, due to a complicated and fragmented LA River governance structure that includes the USACE (the entity with jurisdiction over the channel), the County (the agency overseeing flood control), and local governments with property located adjacent to the river. These conflicts persisted despite efforts to promote

cooperation through the recommendation of a coordinating River Authority that could streamline restoration.

Concerns about personal gain in the LA River case also contributed to lack of a collective vision; these concerns were practically absent from the KK River case. Many interviewees thought LA elected officials used the river to advance political interests and nonprofits possessed financial motivations. There were also concerns about economic benefits of restoration accruing LA River elites, including real-estate developers, land-use attorneys, and wealthy land owners (Hawthorne, 2016).

3.2.2.2. Conflicting goals. In both cases, multiple, potentially incompatible, visions are moving forward at once, especially so in the LA River. For example, there are tensions between goals to increase open space or build new housing around the river; improving environmental outcomes; social cohesion; economic benefits; water reclamation vs. recreation; increased stormwater infiltration vs. protecting infrastructure from flooding; and new development vs. keeping future options open (Blackmore, 2015). KK River interviewees, by contrast, seemed more aware of conflicting goals. For example, the TRC decided to minimize home removal to reduce negative neighborhood impacts and implement the option preferred by two-thirds of residents (Couch, 2012). However, the decision to limit channel expansion created the need for more structural flood management mechanisms and therefore less river restoration.

3.2.2.3. Institutional constraints. Interviewees commented that RD processes have largely been excluded from traditional planning institutions, particularly in the LA River. These constraints include bureaucratic requirements, organizational culture, and other factors, such as limiting paradigms, and lengthy processes that lack flexibility. KK interviewees did not highlight these constraints in their discussions, though they did not explicitly say they were absent.

3.2.2.4. Implementation challenges. Interviewees from both cases highlighted implementation challenges as project barriers. These included delays and sequencing changes, which created a loss of momentum and lack of confidence in the restoration process. Concerns about funding were also present in both cases. They were most prevalent in LA, where nearly every interviewee worried about a lack of funding. In contrast, the KK River project is funded by a dedicated funding source from MMSD. However, KK River stakeholders recognized that long-term success would require maintenance funds, which could be difficult to obtain.

3.2.2.5. In-the-box-thinking. Opinions varied in both cases regarding how transformative restoration should be. Some interviewees called for bold, revolutionary plans, while others were content to work within the physical constraints of the existing channel and the cultural constraints of the existing socioeconomic system. There was also evidence of mechanistic, 'engineering resilience' approaches in both cases (Holling and Gunderson, 2002; Holling, 1996). For example, there is an ongoing debate about whether the proposed level of ecological restoration is sufficient in the KK River, with some interviewees calling for a more ecological, watershed approach. In LA, there is also concern that mechanistic approaches dominate and projects are implemented ad hoc, missing the connection between long-term holistic watershed and river health (Sahagun, 2017).

3.2.2.6. Broader socioeconomic challenges. A failure to address holistically broader socioeconomic components of watersheds means that restoration could exacerbate homelessness, housing unaffordability, gentrification, and displacement. In LA, it also appeared to reinforce a people/environment dichotomy. In this case, the region's acute socioeconomic inequality challenges, including "privatization of the public sphere, the worsening disparities of wealth and power between the many and the few" (Kreitner, 2016), gangs, homelessness, and very unaffordable housing are all serious concerns. Gentrification concerns now drive "the conversations around the river more than the desire to restore the river" (Waterways Advocate). LA River interviewees were very aware of the need to address gentrification, affordable housing, and community identity. Gentrification was less prominent in the KK River, but providing new affordable housing for people displaced by the project was a specific concern. Regardless, failure to counter gentrification pressures in both instances could perpetuate broader unsustainable inequality trends.

4. Discussion

4.1. RD Evaluation Tool

We created the first iteration of the RD Evaluation Tool to contribute to the growing body of scientific and practitioner work calling for holistic sustainable development indicators and tools (e.g., Bastianoni et al., 2019; Boyle and Kay, 2008; du Plessis and Brandon, 2015). The tool satisfies the criteria for holistic sustainable development indicators revealed by our in-depth review of literature and practice in the fields of complex adaptive systems, ecology, sustainability, and regenerative development revealed. The tool moves beyond prescriptive checklists and seeks to characterize the direction of development of a living system and its self-organizing capacities, not end states. It seeks to catalyze systemic regeneration by: 1. Guiding and developing the thinking and actions of communities implementing it to contribute continuously to healthier system functioning; 2. Integrating ecological, sociocultural (e.g., essence, worldviews, paradigms, and values), spatial, and temporal dimensions of living systems and their dynamic relationships as well as the process and product domains of development, planning, and design initiatives; 3. Reflecting how whole, healthy living systems function, incorporating the most recent understandings in ecology and complex adaptive systems science; 4. Providing general living systems principles that should be made locally specific; 5. Being adaptive and iterative; and 6. including quantitative and qualitative components (Bastianoni et al, 2019; Berke, 2002; Boyle and Kay, 2008; Cloutier et al., 2014, 2018; du Plessis and Brandon, 2015; du Plessis and Cole, 2011; Feleki et al., 2018; Gibbons et al., 2018; Gunderson and Holling, 2002; Holling, 1973, 2004; Jørgensen et al., 2015; Kay, 2008; CLEAR, 2017; Pupphachai and Zuidema, 2017; Regenesis Group, 2016; Reed et al., 2010; Waltner-Toews and Kay, 2008; Walker et al., 2006; Wu, 2010).

While some authors suggest that first identifying human values and then constructing RD metrics and indicators might be appropriate (e.g., Hes and duPlessis, 2015), we suggest that human values that are misaligned with the principles of regenerative living systems are the root cause of unsustainability (du Plessis, 2012). Therefore, we constructed our RD Evaluation Tool to develop greater understanding in inhabitants of a place about how it could function regeneratively as well as foster values, worldviews, and behaviors that support regenerative development. Then, within this framework and understanding, what inhabitants appreciate and value about their place can be incorporated into manifesting its potential (see also Reed, 2007). The RD Evaluation Tool is designed to be used at any focal scale as well as across scales, since it is intended to elucidate elements and relationships necessary for nested regenerative living systems. However, the RD Evaluation Tool could be particularly useful at scales where social/co-learning, co-design, co-production, and co-development could have a major impact on system trajectories, such as the neighborhood/community scale, the city/landscape scale, and the bioregional scale (Bai et al., 2016; Bos et al., 2013; Gibbons et al., 2018; Reed et al., 2010; Voorberg et al., 2013; Webb et al., 2019). At these scales, sustainability scientists and practitioners are searching for ways to implement and adaptively monitor such collaborative learning processes so that local communities can develop the capacities for continual improvement (Boyle and Kay,

2008). This tool could provide a way for inhabitants to understand their place better, understand how it could function regeneratively, and develop the deep care, will, and capabilities necessary to manifest its potential.

The RD Evaluation Tool could be applied to an already existing project, such as the case studies of river restoration projects we evaluated, or it could be used from the inception of a project to help guide its processes and outcomes. For example, we make suggestions below for how the KK and LA River restoration projects can shift more towards regeneration based on our evaluation (see *4.2.2. Increasing Engagement with Regenerative Development*). However, once projects and systems are following a resource-intensive pathway with patterns in place, it is very difficult to change them (Gunderson and Holling, 2002; Kay, 2008; Meadows, 1999). Alternatively, if the RD Evaluation Tool is implemented at the beginning of a project, the entire aim of the project can shift to manifesting potential by developing regenerative capacities of living systems across scales. All processes and products of development can be guided and evaluated for alignment with RD Principles and Core Characteristics of Regenerative Living Systems using the tool.

The main objective of the RD Evaluation Tool is to support the development of regenerative thinking in inhabitants of a place. Therefore, implicit in the Tool is the process of asking guiding questions as a community, which is critical for developing regenerative thinking and capacities in dynamic, emergent, self-organizing social-ecological systems (CLEAR, 2017; Mang et al., 2016; Regenesis Group, 2016; Wahl, 2016; Waltner-Toews and Kay, 2008). Asking the right questions can "transform consciousness and thereby create cultural and behavioral change" (Wahl, 2016, p. 21) that supports thriving living systems. Questions include "How can ecological and social diversity be included in RD as a process and in the products of the process?", "How can ecological and social diversity enhance one another?", "How can enhancing diversity in RD processes and products contribute to social learning", "What kinds of social and ecological feedbacks could be effective to increase whole system vitality?", "How can the focal system increase flows of material, energy, and information in the next higher scale?", "How can inhabitants of this place develop an understanding of the interdependence of all life and a sense of responsibility through RD processes and products?", "Which collaborators could help catalyze a systemic shift?", and more. Continually and collectively asking questions ensures that we are reflecting, learning, adapting, and evolving—a feedback mechanism for humans *interbeing* with the rest of life in mutually beneficial ways (du Plessis and Brandon, 2015; Meadows, 1999; Reed, 2007; Wahl, 2016).

4.2. Case studies

4.2.1. Engaging with RD

A greater degree of engagement with RD in the KK River case seems to be correlated with smaller overall system size, a greater degree of familiarity with and implementation of systems thinking, and visionary leaders. These factors have been associated with a greater degree of project success (Bai et al., 2016; Gunderson and Holling, 2002; Habtemariam et al., 2019; Mang et al., 2016; Reed, 2007), making it more likely that a collective guiding vision will be adopted and followed, with fewer insurmountable barriers. In the KK River case, some barriers were still present, but they did not seem to be as much of a hindrance to the project as in the LA River case. In the LA River case, its larger size and higher complexity is likely correlated with the greater degree of barriers to engagement with RD it faced compared to the KK River case. The LA River is six times longer than the KK River, and the watershed is 33 times larger. LA also has a history of fragmentation, complicated jurisdictional issues, and major socioeconomic challenges. These factors likely contributed to lack of a collective vision and conflicting goals for the river restoration project as a whole, which affect every other aspect of the project. For example, smaller projects and programs were not complementary or coordinated in service of a larger collective vision, and thus there was no will to change institutional constraints in service of a collective vision. A collective vision is critical for meeting RD principles, and it requires that diverse individuals come together in an environment of mutual respect and social learning to agree on common goals to benefit the greater whole (Mang et al., 2016; Reed et al., 2010).

4.2.2. Increasing engagement with regenerative development

Although there was more engagement with RD Principles in the KK River project, both projects have many opportunities to shift significantly towards regenerative development in every area. This is not surprising, since both projects are situated within large urban areas that have experienced many decades of unsustainable and degenerative human actions and since a living systems (i.e., regenerative) approach has not been implemented intentionally. It is beyond the scope of this paper to make a complete set of suggestions for how each project could shift more towards RD, and doing so would require a co-creative process with the inhabitants of each living system (Mang et al., 2016). However, we do make some suggestions to illustrate a few important ways in which the projects can shifts. For example, both projects could do more to foster holistic thinking in both project team members as well as inhabitants. They could conduct RD or systems thinking trainings, implement more processes and projects that make human-nature connections clear, and include more regenerative components and relationships in their approaches. Social learning could be improved in both cases, particularly in the LA River case. Both projects could adopt co-creative, diverse, deeply participatory design and planning methodologies instead of typical modes of participation (i.e., choice-based, self-selection). Both could shift to manifesting potential instead of focusing on solving problems. They could more intentionally work across scales to add value and increase connectedness, modularity, and more. They could identify and act on nodal intervention points and work to create guilds to do so.

The correlations to engaging with RD as well as barriers to engagement that our case study analyses revealed are elements included in our RD Evaluation Tool; thus, the tool could provide a framework to transform constraints and trade-offs into opportunities. It has the potential to unite diverse stakeholders across jurisdictional, institutional, social, and cultural boundaries. Inhabitants can become more empowered and invested in regenerative processes and outcomes by focusing on manifesting potential across scales instead of solving problems. It could increase inhabitants' understanding of and connection to place through deep participation in every aspect of projects, from inception to adaptive management (Mang et al., 2016; Mang and Reed, 2012; Reed, 2007). By promoting community collaboration, diversity, learning, and explicitly working to shift worldviews to holistic ones in inhabitants, the tool addresses root causes of (un)sustainability and has the potential to foster regeneration (du Plessis, 2012; Meadows, 1999; Reed, 2007; Reed et al., 2010). At an institutional level, the RD Evaluation Tool could support the necessary flexibility and space for regenerative processes to take place. In combination with the other sociocultural aspects included in the tool, a regenerative culture can be co-created that could self-propagate and catalyze regenerative shifts (du Plessis, 2012; Mang and Reed, 2012; Wahl, 2016).

Intentionally implementing a RD process, guided by RD evaluation tools, from the beginning of any project could be more effective than implementing it later in the process since system trajectories are difficult to shift and more coherent RD efforts are more successful (Benne and Mang, 2015; Mang et al., 2016; Meadows, 1999; Reed, 2007). In large and complex projects, such as the LA River project but also the KK River project, adopting a regenerative landscape development approach could be helpful (Gibbons et al., 2018). Regenerative landscape development considers the landscape as a holarchy (i.e., nested sets of whole living systems) with larger scales providing guidelines for approaches based in lower working levels, smaller scales providing the mechanisms driving higher-level processes, and flow occurring across

scale both vertically and horizontally (Cumming, 2016; Gibbons et al., 2018; Gunderson and Holling, 2002; Koestler, 1978; Kay, 2008; Wu and Loucks, 1995). In other words, networked, nested 'communities of communities' would be co-created throughout the landscape, following RD Principles and Core Characteristics of Regenerative Living Systems (Bai et al., 2016; Daly and Cobb, 1994; McHale et al., 2015; Wallner et al., 1996). Rivers, in particular, can be catalysts for landscape regeneration since they connect most elements of living systems (Forman, 2008; Musacchio, 2009).

4.2.3. Potential place-based RD indicators

LA and KK River document analysis and interviews coupled with our literature and practice review provided insights into potential place-based RD indicators that follow the guidelines laid out in the RD Evaluation Tool. Indicators might include permeability; river and tributary connectivity; integrated and watershed-wide planning; diversity, inclusivity, and thoroughness of public participation processes; co-creativity of plans, design, programs, etc.; social learning; complementary goals, programs, and approaches; common visions; number of inhabitants and frequency of participation in river clean up, citizen science, and similar programs; sense of community ownership of projects and programs; multifunctional land uses, programs, plans, and design; local economies; relocalized flows of water, money, energy, organisms, information, nutrients, etc.; community-led governance; ecological design; collaborations; visionary leadership; species and functional diversity and redundancy; and water quality and flow patterns (Bouska et al., 2019; du Plessis and Brandon, 2015; Reed et al., 2010; Wahl, 2016).

4.3. Future RD Tool development

The field of RD as a whole is nascent but developing rapidly and needs RD tools to support it (Gibbons et al., 2018). The research reported here is intended to contribute to advancing the field, but it is limited in several respects. First, an RD Evaluation Tool, although necessary, is only one component of a larger RD process that must be considered. Additionally, we believe that creating a broadly user-friendly and comprehensive RD Evaluation Tool will require collaborative effort between RD practitioners and scientists. Our sample size was small (i.e., two projects), and our data collection was remote, restricted, and short-term (i.e., the authors were not directly involved in the projects). Finally, there exists inherent researcher and participant bias. We address these limitations below and make suggestions for future RD tool development that could advance the field.

4.3.1. RD indicators and strategies

Working from RD Principles and Core Characteristics of Regenerative Living Systems included in the RD Evaluation Tool, we recommend expanding the tool to include general sets of RD Indicators and Strategies that can then be made specific to place. For example, our in-depth review of literature and practice, as well as our case study analyses, revealed potential RD indicators and strategies that could be grouped into categories, as we did with RD Principles and Core Characteristics of Regenerative Living Systems. More specific RD indicators, strategies, and monitoring projects should be co-created and co-implemented with inhabitants so that they are meaningful, develop care and will, and shift worldviews (Boyle and Kay, 2008; du Plessis and Brandon, 2015). Indicators should elucidate and strategies should support the developmental trajectory of critical functions that govern living system viability and vitality, such as cycles, flows, exchanges, diversity, primary productivity, nutrient levels, subsidiarity, and holistic systems thinking and acting (Boyle and Kay, 2008; Gunderson and Holling, 2002; Holling, 2004; Abson et al., 2017; Rapport et al., 1998; van der Ryn and Cowan, 2007; Wu and Loucks, 1995). Indicators and strategies should be appropriate to scale, since different ecological and sociocultural processes and functions are more influential at different scales (Gunderson and Holling, 2002; Walker et al., 2006; Wu and Loucks, 1995).

4.3.2. RD process tool

Our work has revealed the need for overarching RD process tools that can guide development and design processes at a variety of scales, but particularly at the landscape scale (i.e., a heterogenous area of a size between regions and towns (Forman, 2008)) and its immediate connecting scales—bioregions, cities, and neighborhoods/communities. Some useful RD process frameworks exist (e.g., TRP, LENSES), but they are general and not specific for the landscape and connecting scales; they could include more explicit integration of landscape-scale dynamics and complexities (see Gibbons et al., 2018; Wu, 2013). Similarly to the RD Evaluation Tool, process tools would help guide inhabitants through a process of deepening understanding, care, and will to regenerate their places (Reed, 2007). They would work across scales in landscapes to create connected, networked, nested communities of communities for regeneration in landscapes (Bai et al., 2016; Daly and Cobb, 1994; Gibbons et al., 2018; McHale et al., 2015; Wallner et al., 1996). Researchers and practitioners could enhance already existing RD, design, and development processes, making them more complete, rigorous, and capable of integrating large, complex landscape dynamics by incorporating more scientific knowledge and techniques from fields such as landscape ecology, GIS, and sustainability (Gibbons et al., 2018). As mentioned above, such a process tool could be used from the beginning of development projects to eliminate barriers to RD. RD evaluation tools and indicators would work complementarily with RD process tools, guiding specific actions, indicators, strategies, and decisions within the RD process.

4.3.3. Integrated research and practice

Further integrated research and practice iteratively creating, implementing, evaluating, and adjusting the RD Evaluation Tool and other RD tools and processes through collaborative workshops, design experiments, adaptive management, and similar integrated research-practice would help advance RD and holistic sustainability (Boyle and Kay, 2008; Felson and Pickett, 2005; Gibbons et al., 2018; Gunderson et al., 1995). It is necessary to know if tools are achieving their intended aims, how processes and systems guided by RD tools are developing over time, how RD tools and processes might be best adapted to work at different scales, and how to best incorporate new information from science and practice into tools.

5. Conclusions

Our intention is to contribute to science and practice advancing holistic ecological and sustainability indicators and tools that reflect the nature of complex adaptive systems. Such tools would allow for the dynamic, emergent, relational nature of whole living systems. They would seek to characterize the direction of development of a living system and its self-organizing capacities rather than end states. Most importantly, they would contribute to developing a regenerative mindset, i.e., help shift the thinking of the inhabitants of a place toward a holistic worldview. The emerging field of regenerative development (RD) offers theoretical and practical guidance for such indicators and tools. We integrate complex adaptive systems science, ecology, sustainability, and regenerative development to construct and pilot the first iteration of a holistic sustainable development evaluation tool—the Regenerative Development Evaluation Tool—in two river restoration projects. The tool identifies RD Principles and Core Characteristics of Regenerative Living Systems. It mimics living systems in that it is hierarchical, living (i.e., adaptable), relational, and developmental, intended to increase the capacities of humans to be regenerative change agents in living systems. It integrates ecological and sociocultural dimensions of living systems with process and product domains of development and design activities. The tool is intended to provide general

guidance for thinking and decision-making that should be made specific and place-based through a co-creative community process.

Our comparative case studies analyses revealed that visionary leaders, smaller system size, and greater degree of living systems thinking correlated with greater degree of RD engagement. Barriers to engaging with RD and living systems thinking, more generally, could be overcome by intentionally implementing an RD process from the beginning of a project. In large and complex sustainability projects, a regenerative landscape development approach, which integrates social and ecological landscape elements as a holarchic living system, could be very beneficial. Analyses also revealed potential place-based indicators for each case.

Underpinning the theory and practice of RD is a holistic worldview and regenerative thinking (Gibbons et al., 2018; Mang et al., 2016). In the western world, and, increasingly, the non-western world, a mechanistic worldview and reductionistic thinking predominate and are incredibly difficult to change (Abson et al., 2017; du Plessis, 2012; Meadows, 1999). According to RD practitioners, developing a regenerative mindset takes time, commitment to continually and intentionally developing the self in relationship to the larger systems of which one is a part, and leaders who commit to developing others regeneratively (Mang et al., 2016; Regenesis Group, 2016). RD evaluation tools and indicators should support these aims. The main objective of any RD tool, and the main objective of the RD Evaluation Tool presented here, is to support developing in the inhabitants of a place a regenerative mindset so that they can act intentionally in living systems in ways that catalyze systemic health. Continuing to develop and implement RD tools and practice, incorporating RD into professional trainings and academia, and continuing to integrate fields that are based on a more holistic worldview, such as complex adaptive systems and ecology, can help achieve necessary shifts in thinking.

To support the necessary shifts in thinking to co-create thriving living systems, we recommend continuing the development and expansion of the RD Evaluation Tool, adding RD Indicators and Strategies that can be guided by RD Principles and Core Characteristics of Regenerative Living Systems included in the tool. We also recommend developing an RD process tool that can work explicitly across scales, integrating the neighborhood, city, landscape, and regional scales since they are pivotal for sustainability efforts and manifesting thriving living systems. These tools could be developed following a similar methodology to the one presented in this paper, iteratively integrating relevant scientific and practitioner knowledge and testing tools through engaged research. Since RD is an on-going, place-based developmental change process, long-term integrated research and practice provides an ideal methodology to test and adapt RD tools and processes that are meaningful in local contexts and build transferable RD theory. Ultimately, RD tools will be most impactful as part of a regenerative culture and lifestyle (see Wahl, 2016). We suggest the field of sustainability move in the direction of supporting regenerative cultures in order to manifest the inherent capacity of living systems to be thriving, not just sustainable.

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