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Ecological restoration of the Los Angeles River provides natural and human benefits as part of a virtuous socioecological cycle

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Ecological restoration in the Los Angeles (LA) River watershed is proceeding on multiple fronts with the support and engagement of diverse stakeholder groups. Pilot projects to restore habitat, reintroduce native species, and design science-based ecosystem enhancements have produced real benefits to nature and people and demonstrated the potential for additional benefits. The pilot projects, which are in various stages of collaborative planning and implementation, have generated increased interest and financial support to further their implementation and maximize socioecological co-benefits. This self-reinforcing positive feedback is an example of a virtuous cycle established through a combination of long-term environmental planning, community-building, and watershed-scale scientific study to gain the support of stakeholders and align ecological intervention (i.e., restoration) with the plans and policies of governments, resource managers, conservation groups, and grassroots advocacy groups. Conservation and restoration projects targeting iconic and protected focal species can be an effective means of leveraging these interests and building support. For example, the LA River Fish Passage and Habitat Structures project addresses a critical limiting factor for the recovery of endangered steelhead trout (*Oncorhynchus mykiss*) while also enhancing urban biodiversity and providing recreational opportunities and other beneficial uses (e.g., ecosystem services) for the surrounding communities. Through these efforts, our planners, ecologists, and engineers are using place-based conservation to demonstrate solutions to problems that affect people and nature in other urban landscapes. Here, we show how this work can provide socioecological benefits in disadvantaged communities and also generate public awareness and motivation to perpetuate the cycle of positive feedback.

KEYWORDS

virtuous cycle, biodiversity, ecosystem services, conservation, urban river, restoration, steelhead

Introduction

As global populations have moved from predominantly rural to majority urban living, urban rivers are increasingly seen as opportunities to improve ecosystem services and biodiversity (Costa et al., 2010; Schneiders et al., 2011; Everard and Moggridge, 2012; Francis, 2012). Urban rivers potentially provide numerous ecosystem services that benefit humans and their wellbeing (e.g., flood protection, cultural heritage, recreation) (Millennium Ecosystem Assessment Program [MEA], 2005a,b,c), but development has degraded rivers to the extent they often no longer can provide these services (Carpenter et al., 2009; Everard and Moggridge, 2012). Preservation and enhancement of biodiversity is also increasingly a focus of urban ecology since biodiversity increases the resiliency of ecosystems to perturbations like climate change that would reduce their ability to provide ecosystem services (Carpenter et al., 2009; Schneiders et al., 2011).

The virtuous cycle framework for conservation seeks to simultaneously address ecosystem service needs and the broader benefits of biodiversity by highlighting the relationships between places, people, and biodiversity that are essential to developing conservation projects (Morrison, 2015). Morrison (2016) describes a virtuous cycle framework in which conservation projects can be designed to promote engagement and further action by stakeholders as the benefits of conservation accrue, producing a durable, self-perpetuating cycle of improvements in both ecosystem services and biodiversity. Virtuous cycles can operate at a range of spatial scales (e.g., river reach or watershed), with virtuous cycles at different scales often supporting one another (Morrison, 2016). In this article, we present an example of a virtuous socioecological cycle fostered in the Los Angeles (LA) River watershed by numerous science-focused conservation projects that have generated burgeoning momentum and support by aligning with stakeholder priorities and addressing societal and ecological needs. We describe steps and key elements of the LA River watershed-scale virtuous cycle, with examples illustrated by several pilot projects at the reach scale. Because our example projects are still in planning and early implementation phases, their conservation benefits are envisioned but not yet fully realized.

A river reborn—Starting a movement

A primary challenge of the virtuous cycle at any scale is developing the initial critical mass of engaged stakeholders and conservation projects such that sufficient positive outcomes are created to motivate future actions. The creation of a movement where individuals, agencies, and organizations are supportive, engaged, and inspired to take additional actions is vital to creating a self-perpetuating virtuous cycle that can achieve positive conservation outcomes for people and nature.

Creating a virtuous cycle for people living in LA, who do not realize that the concrete drainage system running through one of the most densely populated areas of the United States was once a natural river, took decades. Among the challenges was, and still is, convincing residents that the drainage was once a free-flowing river with native fish and that it is possible to bring nature back into the built environment. To most, the LA River, which was once the sole source of water for the City of LA and habitat for the iconic Southern California steelhead trout (*Oncorhynchus mykiss*, herein steelhead), is a no man's land, fenced, and forgotten. A "River Movement" advocating the socioecological value of the LA River and the potential for its restoration began in 1986 with the founding of Friends of the LA River (FoLAR) (Friends of the La River [FoLAR], 2021). In 1996, LA County adopted the LA River Master Plan creating a vision for bike paths, parks, and other amenities along with the 51-mile LA River (Los Angeles County, 1996). The Master Plan illustrated the possibilities for improving access to nature and enhancing biodiversity in the urban riverscape and vastly increased visibility and understanding of how these improvements would benefit human wellbeing.

In the decades since the Master Plan, conservation efforts to restore habitat, reintroduce native species, and design science-based ecosystem enhancements have produced multiple socioecological benefits. Pilot projects in the watershed have generated increased interest and financial support to further their implementation and align their objectives with ecological and social priorities. This self-reinforcing positive feedback is an example of a virtuous cycle established through a combination of long-term environmental planning, community-building, and watershed-scale scientific study to gain the support of stakeholders and align habitat and flow restoration projects with the objectives of government, resource managers, and conservation/advocacy groups.

Strategies to engage stakeholders in the virtuous cycle

Target species restoration opens doors for community engagement

A target/focal species approach to ecosystem restoration has proven to be an effective framework on which a virtuous cycle of ecosystem restoration is being built in the LA Basin. Using a focal species approach that is founded in multidisciplinary science and explicitly strives to achieve multiple socioecological benefits at a watershed scale, steelhead serves as an umbrella species whose restoration and return to the LA Basin will require multiple beneficial improvements to the ecosystem with

intended positive outcomes for native species and habitats, as well as people. Within this framework, targeted focal species restoration efforts can be designed as multi-benefit projects that engage numerous stakeholders in the virtuous cycle while using the recognition of the focal species to generate enthusiastic support among a wide range of stakeholders (Novacek, 2008; Qian et al., 2020). This multi-benefit focal species approach is fully compatible with the current paradigm in ecological restoration that recognizes linkages among social and ecological systems and emphasizes the need for multi-benefit goals as foundational to the success of conservation, restoration, and management efforts (Wallace et al., 1996; Apitz et al., 2006; Gardali et al., 2021). In fact, it may be a particularly effective catalyst for a virtuous cycle in an urban setting because it provides a focused, recognizable foundation for ecological and social benefits that are manifested in, of, and for the city (Pickett et al., 2016). Because familiarity and positive associations with species have been found to increase individuals' willingness to pay for conservation more than ecological-scientific factors (Martín-López et al., 2007), iconic focal species that are well-known to the public and stakeholders, and indicators or keystone species are considered highly suitable targets for urban ecosystem restoration. Where they are present or potentially present, species listed as threatened or endangered are an effective choice as focal restoration species as they are especially well-known and important to many stakeholders (Qian et al., 2020). Such species are the subject of legal protections, inherently generating support from regulatory agencies and conservation organizations, opening doors to funding, and building a virtuous cycle.

The Southern California steelhead is listed under the federal and state Endangered Species Acts and is the subject of a federal Restoration Plan (National Marine Fisheries Service [NMFS], 2012), making it an ideal focus for regional river restoration and conservation efforts. This species is the current focus of restoration efforts in the LA River, including the Los Angeles River Fish Passage and Habitat Structures (LAR FPHS) project being implemented under the watershed-wide LA River Fish Passage Program (LAR FPP), and related efforts in the lower mainstem LA River and the Arroyo Seco, a headwater tributary. The focus on steelhead has helped generate support and involvement by the public and other groups including the National Marine Fisheries Service, California Department of Fish and Wildlife (CDFW), Arroyo Seco Foundation (ASF), the LA Mayor's Office, CalTrout, Trout Unlimited, and others.

Aligning federal, state, and local policies, programs, and plans

Alignment of restoration with environmental regulations, adopted plans, strategic initiatives, programs, and projects at all levels of government, is critical to fostering the conditions for a virtuous cycle. When a conservation project is undertaken, regulatory and resource agencies [e.g., U.S. Army Corps of Engineers (USACE), CDFW] are one of the categories of stakeholders that must be engaged to promote a virtuous cycle since their approval or participation (e.g., permits) is needed to advance the project. Alignment helps the agencies achieve their goals and motivates them to support and advance the project. Direct involvement in and approval for a conservation project by these agencies also communicates to other stakeholders that the project is beneficial to a resource, building the momentum and broader support for conservation projects that promotes the virtuous cycle (Morrison, 2016).

The LAR FPHS project engages the support of regulatory and resource agencies by incorporating alignment with policies, programs, and plans such as the City of LA Biodiversity Report (City of LA, 2020) and the LA River Ecosystem Restoration Integrated Feasibility Report (USACE, 2015) along with highlighting how it advances the objectives of the LA River Ecosystem Restoration and Recreation Project (LARERRP), the City of LA, and the USACE (Stillwater Sciences, 2022). Alignment can also lead to agency actions that advance the project. The LARERRP was designated as a P3/Alternative Delivery pilot project by the USACE due to its alignment with USACE objectives (City of LA, 2021). Wider alignment also promotes the virtuous cycle by providing tangible examples of how agencies can work together to further their different goals, facilitating future collaborative efforts, and reducing the likelihood of conflicts that would impede future projects.

Enhancing ecosystem services provides societal benefits

Conservation objectives aimed at preventing extinction and advancing the recovery of endangered species appropriately and justifiably focus on benefits to nature (e.g., habitat improvement, population expansion) without an explicit focus on societal benefits, but conservation projects in a virtuous cycle, especially those in urban environments, must consider how outcomes will affect adjacent communities (Morrison, 2015, 2016). Conservation projects are better able to motivate communities, Tribal Nations, and other local stakeholders to participate in the virtuous cycle by understanding the ecosystem services the project site provides to those living near it and incorporating enhancement of those ecosystem services into a conservation project. Ecosystem services are used to help muster support for conservation by assigning a quantitative (e.g., monetary) or qualitative (e.g., cultural identity) value to conservation outcomes and justifying conservation objectives relative to society (Costanza et al., 1997; Bullock et al., 2011; Seppelt et al., 2011). While the monetary valuation of ecosystem services can provide useful information to guide conservation, it is also important to incorporate ecosystem services that are valued by local communities but cannot easily be assigned a monetary value into conservation projects to generate the

enthusiasm to engage these communities in the virtuous cycle and foster community support of elected officials who support conservation.

In the urban environment along with the LA River where access to nature is sparse, conservation projects often include enhanced access to nature and recreation since those are key ecosystem services local communities frequently list as important to them. Channel redesigns for the LAR FPHS project specifically took into consideration how the conversion of barren concrete to vegetation along with the channel enhances access to nature along with the river and improves the kayaking experience (Stillwater Sciences, 2022). The LARERRP also enhances access to nature and recreation for local communities along with the river by including new parks, vegetating barren concrete, and constructing wetlands along with the LA River (City of Los Angeles [City of LA], 2016).

Regional conservation projects promoting the virtuous cycle

Steelhead recovery projects across the Los Angeles River watershed

Efforts to facilitate steelhead recovery along with the length of the LA River have built support for restoring the river and its tributaries by highlighting how conservation projects for steelhead can provide multiple benefits. The LAR FPP consists of a series of fish passage and habitat structure design pilot projects to restore fish migration from the ocean to spawning habitat in the upper tributaries. As the first of several projects under this program, the LAR FPHS project (Stillwater Sciences, 2021, 2022) and the Conceptual Ecological Model and Limiting Factors Analysis for Steelhead in the LA River watershed (Limiting Factors Analysis, or LFA) (Stillwater Sciences, 2020) have been especially influential in catalyzing a movement by bringing together stakeholders to form a collective vision for steelhead recovery in the LA River watershed.

The LAR FPHS project demonstrates how a target species conservation approach for steelhead can also be developed as a multi-benefit project that simultaneously advances the goal of restoring steelhead to the LA River while being consistent with the goals of local communities, conservation organizations, and numerous agencies (**Figure 1**). The LAR FPHS project advances the local, reach-scale, and watershed-scale virtuous cycles of LA River conservation by ensuring that its own goals align with the goals of related agency-developed plans. The broad alignment of the LAR FPHS project with these goals and the support from elected officials, such as Mayor Eric Garcetti, incentivizes these agencies to take action to advance the LAR FPHS project and its conservation outcomes. As a pilot project, it also highlights how a multi-benefit conservation project that advances multiple conservation outcomes can be scaled up and used as a template for other projects within the watershed. One reach of the LAR FPHS is moving into final design and construction, while the overarching LAR FPP creates more momentum for related watershed-wide projects engaging regulatory agencies and community.

The LFA provides the foundational science–based framework for the steelhead recovery efforts in the watershed, including the LAR FPHS, and recommends studies, conservation projects, and planning efforts that should be implemented to advance steelhead recovery within the watershed (Stillwater Sciences, 2020). Its recommendations to build multi-benefit conservation projects by coordinating steelhead-focused planning and conservation projects with watershed-wide initiatives are key to contextualizing how steelhead recovery efforts provide value to a wide range of stakeholders—engaging more groups in a movement and developing funding partnerships. Planning and implementing the steelhead actions in coordination with other plans, projects, and initiatives are key to developing approaches to river-riparian restoration and enhancement that capitalize on synergies and multi-benefit strategies throughout the watershed and the region and perpetuate the virtuous cycle.

Conservation projects within the Arroyo Seco

Vital to steelhead recovery efforts in the LA River watershed is the Arroyo Seco, whose headwaters have cool stream habitat suitable for trout and steelhead. Adopted stakeholder-based watershed plans, including the Arroyo Seco Watershed Assessment, have led to conservation projects like the Central Arroyo Seco Stream Restoration that restore more natural stream conditions for native fish and enhance ecosystem services (e.g., recreation) for the surrounding communities (Arroyo Seco Foundation [ASF], 2008a; ASF, 2011; CDM, 2011). Native arroyo chub (*Gila orcuttii*), a key indicator species for river and riparian health, was reintroduced to this 20-acre restoration area in 2008, and early data indicated they were persisting in the stream and enhancing the local biodiversity (U.S. Army Corps of Engineers [USACE], 2011). CDFW cites it in management recommendations for the species as an example of successful native fish restoration (Moyle et al., 2015).

These projects and activities have advanced the virtuous cycle by generating engagement and enthusiasm for conservation along with the Arroyo Seco and the LA River watershed, as evidenced by ASF's volunteer Trout Scouts, its growing newsletter circulation, and public comments advocating for conservation projects in the watershed (USACE, 2015; Sierra Institute, 2019). ASF and the City of Pasadena also have fostered involvement in the virtuous cycle by annually welcoming hundreds of watershed stewards to assist with native

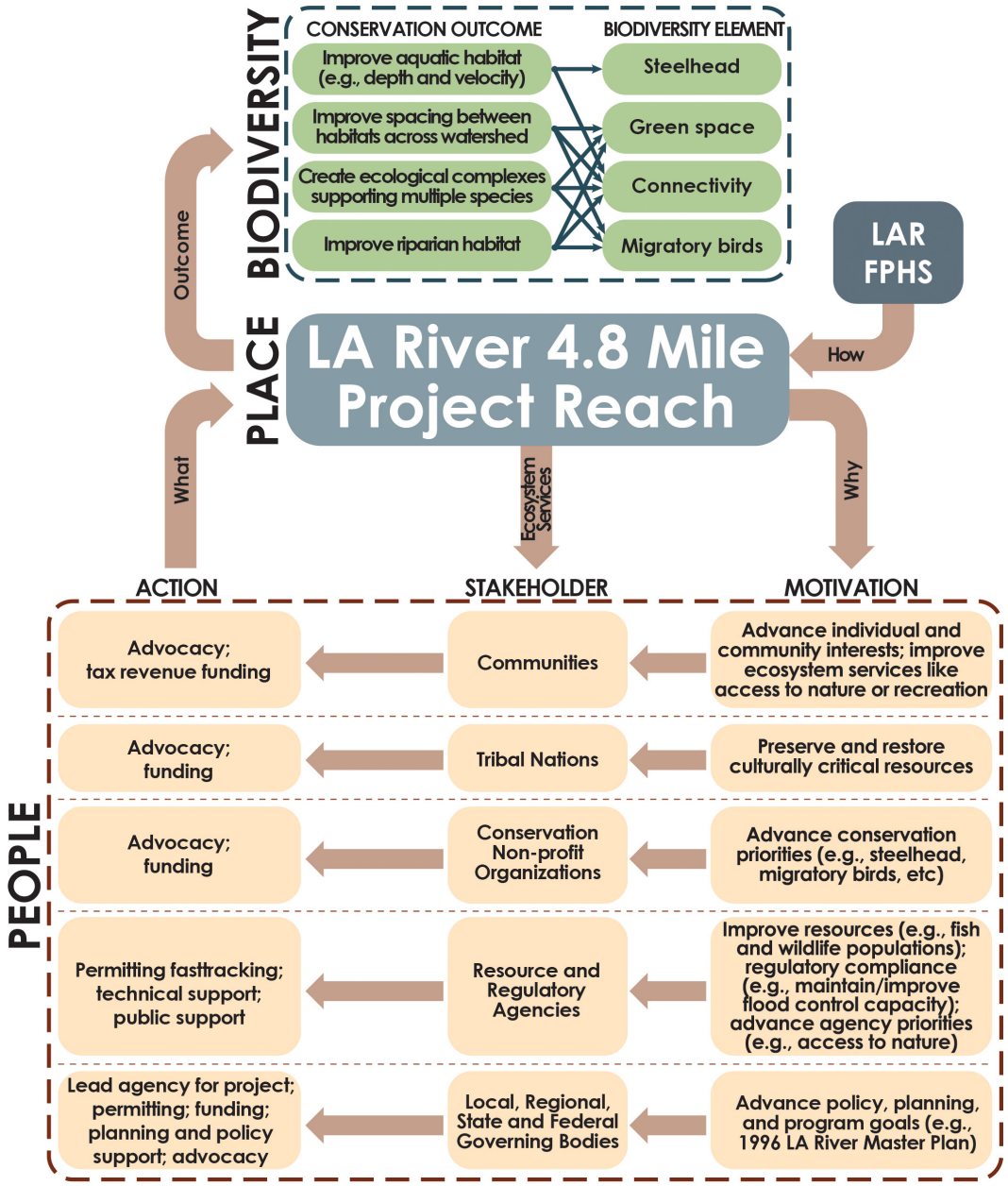

FIGURE 1
The LA River Fish Passage and Habitat Structures (LAR FPHS) project advances a virtuous socioecological cycle in the 4.8-mile project reach of the LA River between the Glendale Narrows and Washington Boulevard. The LAR FPHS is designed to provide motivations for a wide range of stakeholders to take actions to support conservation in the LA River that advances multiple social and ecological priorities and ecosystem services of stakeholders and promotes urban biodiversity. In this diagram, the arrows flow initially from the LAR FPHS project to the "Place" box because it is "how" the virtuous cycle is started. Next, the arrows flow from the "Place" box to the "Motivations" column in the "People" box to highlight how the LAR FPHS project is designed to provide specific motivations for "why" individual stakeholders would want to engage in the virtuous cycle, so stakeholder support is not necessarily dependent on the stakeholders valuing the planned conservation outcomes or biodiversity enhancements of the project. Arrows continue to flow from "Stakeholders" column of the "People" box to the "Action" column to emphasize "what" actions engaged stakeholders can take to support the LAR FPHS in this reach of the LA River. Ecosystem services flowing from the "Place" box to the "Stakeholder" column of the "People" box shows how ecosystem services inherently are provided to stakeholders by the river reach, and enhancements in ecosystem services from the conservation project will provide direct positive benefits to stakeholders that contribute to perpetuating the virtuous cycle. Additionally, there are conservation outcomes flowing from the "Place" box to the "Biodiversity" box that show the conservation outcomes the LAR FPHS is designed to achieve (left column of the top "Biodiversity" box) and how these outcomes enhance various biodiversity elements (right column of the top "Biodiversity" box) within the project reach. Please note that the virtuous cycle shown is a simplified summary that only highlights some of the key components (e.g., stakeholders, conservation outcomes) in this conservation project and the reach of the LA River. An organically self-perpetuating virtuous cycle would expand to engage more stakeholders and produce more conservation outcomes across the LA River watershed.

plantings and other conservation activities. ASF Trout Scouts conduct educational hikes to foster watershed stewardship and recognition that suitable steelhead habitat exists in the upper Arroyo Seco. Stakeholders frequently cite the successes of the Central Arroyo Seco Stream Restoration as one motivation for continuing to push for linked conservation projects and funding opportunities to recover endangered steelhead in the Arroyo Seco and LA River mainstem (Arroyo Seco Foundation [ASF], 2008b; U.S. Army Corps of Engineers [USACE], 2011; USACE, 2014; State of California Wildlife Conservation Board [WCB], 2019; Brick, Arroyo Seco Foundation, personal communication, June 15, 2022; WCB, 2022).

Urban orchard restoration in the lower Los Angeles River

Currently under construction, the Urban Orchard Community Park in South Gate is located along with the lower LA River, connected to the river bikeway and many other parks and recreational opportunities described in the Lower LA River Revitalization Master Plan. A grassroots, community-driven park and orchard developed by neighborhoods, community leaders, schools, and elected officials in partnership with the Trust for Public Land, Urban Orchard is a 7-acre native habitat park with a 1-acre native wetland and trout stream that will provide an oasis for residents to engage in nature-based play, farming fruits and vegetables, celebratory gatherings, and interpretive learning (outdoor classroom) about local flora and fauna (City of South Gate, 2019). The project design, its inclusion of ecosystem services for local residents, and its success at engaging the community, has already become a model for future parks and open space projects throughout the watershed, thus promoting the virtuous cycle.

The virtuous cycle creates its own funding support

The restoration actions described above—from planning to implementation phases—bolster confidence in and support for still greater funding opportunities as the restoration activities align with the programs and strategic goals of funding entities. Each stage of a restoration project contributes to the overall progress of watershed-wide recommendations. For example, the State of California has adopted strategic planning recommendations and goals that guide grant funding opportunities for restoration projects. Likewise, state, federal, and regional entities have adopted similar recommendations that tier off or build upon such restoration strategies—such as conserving 30% of California's land and coastal waters by 2030 (California Natural Resources Agency, 2022). When watershed leaders, such as the City of LA and our LA River and Arroyo Seco restoration teams, intentionally seek funding together for restoration projects under these guidelines, there is greater alignment with stakeholder goals, and systemic momentum is built into the watershed-based restoration process. As the LAR FPHS project has moved through conceptual design to final design, implementation of the first construction phase of the program has attracted even stronger support for implementation of the funding. Other benefits include growing funding awards for the upper tributaries, such as the Arroyo Seco restoration and fish barrier removals. Similarly, funding opportunities in the lower LA River watershed for restoration and fish passage projects have advanced project concepts in tandem. Funders leverage unanimous local support and progress in watershed-based projects, providing funding incentives for construction phases and linked restoration projects.

Discussion

Virtuous cycles promoted by conservation projects influence broader regional conservation outcomes and improvements in biodiversity. As conservation projects such as the LAR FPHS, Urban Orchard, and Central Arroyo Seco Stream Restoration produce improvements in ecosystem services/beneficial uses, local community members are more likely to become engaged stakeholders who take action to promote the local virtuous cycles and/or the broader LA River watershed-scale virtuous cycle. As an example, tangible increases in green space and recreation opportunities within a 10-min walk or a 10-min drive provided by conservation projects in the LA River watershed (**Figure 2**) are anticipated to motivate local residents to become stakeholders and participate in advocacy, action, and/or funding that lead to a watershed-wide self-perpetuating virtuous cycle (Nguyen et al., 2018).

Tangible improvements in one part of the watershed also bring potential stakeholders in other parts of the watershed into the cycle as people and organizations see and experience what is possible along with an urban river. Numerous public comments on the LARERRP, including Arroyo Seco stakeholders, highlight how stakeholder engagement in the Arroyo Seco is extending into other portions of the watershed (USACE, 2015). Successes realized in the LA River watershed may also provide an example for virtuous cycles elsewhere. The following sequential steps have proven successful in generating a self-perpetuating socioecological cycle: (1) develop a science-based understanding of the system (the biodiversity), (2) strive to understand the role and importance of the system to society and stakeholders (the place and its people), (3) identify data gaps, limiting factors, or critical needs for the ecosystem and people, (4) plan and implement conservation projects that align with stakeholder priorities and societal needs, and (5) leverage

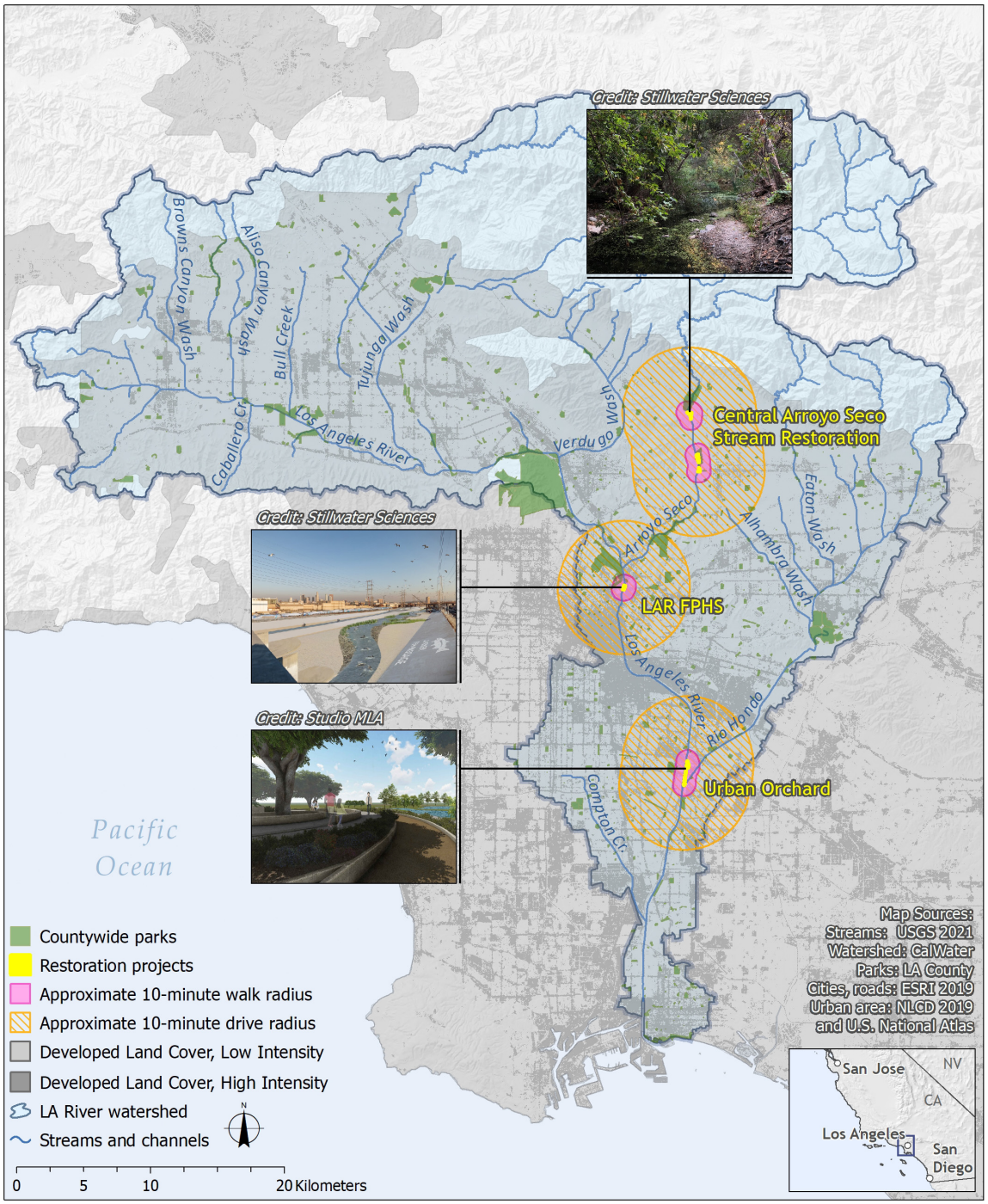

FIGURE 2
Conservation projects often improve ecosystem services for people outside of the direct project footprint, leading to further engagement by existing stakeholders and potentially encouraging new stakeholders to realize the value of joining the virtuous cycle to promote future conservation projects. As an example, the LA River Fish Passage and Habitat Structures (LAR FPHS), Central Arroyo Seco Stream Restoration, and Urban Orchard conservation projects in the LA River watershed enhance green space and improve access to nature and recreational opportunities within a 10-min walk (i.e., 0.8 km) or 10-min drive (i.e., 4.8 km) of those projects in a highly urbanized environment. Such enhancements promote stakeholder engagement in the virtuous cycle by those who want to advance these ecosystem services (e.g., local communities, City of LA, Mountains Recreation and Conservation Authority). Please refer **Supplementary Figure 1** for a visual comparison of pre-project and current or planned post-project improvements for the three example conservation projects. Magnitude of urbanization represented by the intensity of developed land cover using the National Land Cover Database classification of impervious surface percentage. Not depicted here are ecological and recreational benefits associated with enhanced connectivity, both aquatic and terrestrial, within and along with the river channel.

successful outcomes and alignments in efforts to plan and build new projects.

The City of LA is moving forward to restore habitat along with an 11-mile stretch of the LA River from Griffith Park to downtown LA. The LAR FPP is an example of a bold, transformative vision. Ultimately, the LA River can be transformed into an urban green space as iconic as Griffith Park in LA, Golden Gate Park in San Francisco, or Central Park in New York. Community engagement, political will, and funding fueled the creation of and desire for projects that will enhance biodiversity and improve the quality of life for people including disadvantaged communities and Tribal Nations. The virtuous cycle initiated by LA River conservation projects continues to raise awareness that healthy urban ecosystems are a cornerstone of the livability and socioecological wellbeing of LA and are demonstrating that science-based solutions benefiting wildlife and people are not only possible but they are also within our grasp.

Data availability statement

The original contributions presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding author.

Author contributions

WK, AK, and BO conceived the manuscript. AK, NB, and WK organized the text and manuscript. WK, NB, AK, and SB contributed to the manuscript writing. NB, AK, and BO conceived the figures. BO provided an editorial review. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2022.932550/full#supplementary-material

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