Using Social Equity to Inform Urban Stream Management

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ABSTRACT

Advancing social equity and overcoming historical inequities are often central to urban water policy. However, water managers have struggled to include equity in decisions due to a lack of clear planning frameworks and quantitative metrics. In this paper, two stream restoration case studies are described in which equity played a prominent role in decision making. First, census-based equity metrics were used to contextualize decisions and communicate restoration project benefits in the Bronx River in New York City, New York. Second, qualitative equity metrics were used to inform stream restoration decisions in the Beargrass Creek watershed in Louisville, Kentucky. These cases are compared and contrasted relative to the approach for assessing equity, metrics used, decision making methods, complexity of the equity assessment, and gaps in the methods. Ultimately, a set of lessons learned are identified for using equity metrics in complex urban water management decisions.

INTRODUCTION

Societal demands on urban waters vary widely across many objectives, and urban water managers often find themselves trying to meet numerous outcomes simultaneously. Integrated water resource management provides a general framework for coping with decisions laden with trade-offs. This approach is broadly defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an **equitable** manner without compromising the sustainability of vital ecosystems" (Global Water Partnership 2021, **emphasis added**). The "triple bottom line" of economic, social, and environmental outcomes is clearly embedded within this concept. However, equitability of outcomes also figures prominently in this definition and applies to all three elements of this bottom line. Furthermore, the role of equity is currently a primary interest in federal, state, and local policies beyond the urban water management context (e.g., EO 13985, NYSDEC, 2021, Foster et al. 2019, respectively).

Despite the central importance of equity in urban water management, the concept remains underutilized in practice (Langemeyer and Connolly 2020), and water resources professionals often encounter a variety of barriers to including equity in planning processes (Seigerman et al. *In review*). This paper seeks to reduce the barriers to operationalizing equity by demonstrating how the concept was used to inform stream restoration planning in two urban watersheds. To do so, I first describe equity conceptually relative to three primary dimensions. Second, two stream restoration case studies are presented to highlight different approaches for quantifying equity and informing decision-making. Finally, I synthesize lessons learned from these contrasting case studies to guide urban water managers through potentially challenging issues with incorporating equity into project planning.

WHAT IS EQUITY?

There is growing demand by engineers, project managers, researchers, and local communities to include equity in water resources projects. For instance, flood risk management projects may not equitably distribute protective infrastructure because of a focus on metrics of economic efficiency that prioritize higher value properties. Similarly, stakeholders may be interested in equitably distributing the ecological benefits of restoration projects throughout a watershed.

However, this important topic is often not addressed, in part, due to its broad conceptual foundation. Generally speaking, equity means ensuring that people have fair opportunities to participate in society through interconnected dimensions of recognition, procedure, and distribution (McDermott et al. 2013, Montambault et al. 2018, Meerow et al. 2019, Langemeyer and Connolly 2020, Seigerman et al. *In review*). In practice, equity is often focused on how benefits, harms, or risks are distributed within a community, but distributional outcomes only capture one aspect of the concept.

The parts of a tree provide a useful heuristic for thinking about the dimensions of equity (Figure 1, https://n-ewn.org/equity/), and the three major facets of equity can be summarized as follows:

- *Distributional equity* refers to the way in which benefits, harms, risks, opportunities, and resources are allocated within a community. Like the crown of a tree, distributional issues are often the most visible part of equity. For example, equitable distribution of benefits could include ensuring that outcomes from a flood mitigation project are spread fairly across different populations (e.g., according to income, race, age).
- *Procedural equity* refers to fair participation, access, and influence during the decision-making process. Procedures are like the trunk of a tree, providing structure and support for equity and facilitating many of the ways recognition and distribution are connected. From a practical standpoint, procedural equity involves issues like accessibility of public meetings (in time and location), availability of materials in multiple languages, understandability of public communication materials (e.g., minimized jargon), and transparency in the project planning processes.
- *Recognitional equity* refers to the acknowledgment and respect given to people with different life experiences and perspectives. Recognition acts like a root system, anchoring equity through acknowledgment and respect of diversity, and through humility in relation to the perspectives of others.

STREAM RESTORATION CASE STUDIES

In this section, two watershed restoration case studies are presented to highlight different approaches to integrating equity into project planning. A mission-driven Federal agency, the U.S. Army Corps of Engineers (USACE), led both studies. Thus, the projects were guided by agency policies and procedures, which require a modicum of background and context.

The overarching purpose of the USACE ecosystem restoration mission is "…to restore significant structure, function and dynamic processes that have been degraded" (USACE 1999). As such, USACE projects have typically focused on a limited interpretation of this mission as dictated by the Congressionally authorized purposes (i.e., a narrow focus on environmental quality to inform restoration decisions, James 2020). However, water resources projects often influence outcomes beyond their intended purposes, and recent USACE policies have directed teams "to ensure the USACE decision framework considers, in a comprehensive manner, the total benefits of project alternatives, including equal consideration of economic, environmental and social categories" (James 2021). As such, a natural tension emerges between mission-specific project objectives (e.g., ecosystem restoration) and broader national directives for holistic project planning addressing issues like equity (e.g., James 2021, EO 13985). The following case studies demonstrate how two stream restoration teams navigated these challenges.

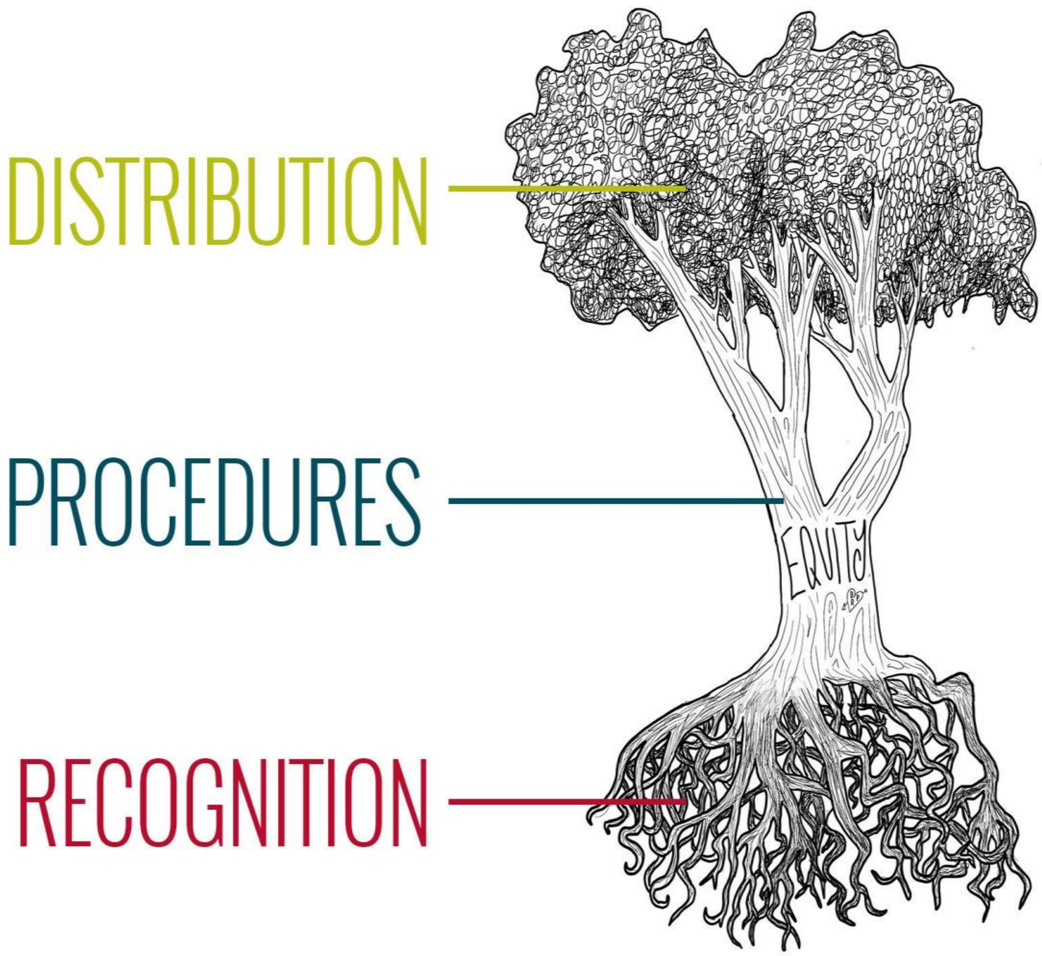

Figure 1. A conceptual model of equity from Seigerman et al. (*In review*) comparing the three dimensions of equity to a tree: distributional equity (the crown), procedural equity (the trunk), and recognitional equity (the root system).

Bronx River, New York, New York. Embedded within the New York City metropolitan area, the Hudson-Raritan Estuary is one of the largest and most urbanized estuaries in the United States and is congressionally designated as an estuary of national importance. Over more than a decade, the USACE and the Port Authority of New York and New Jersey collaborated with more than 120 federal, state, municipal, academic, non-profit, and stakeholder partners to iteratively develop a comprehensive restoration master plan for the region (USACE 2009ab, USACE 2016).

Nine restoration sites were identified for detailed investigation in the Bronx River and are the focus of this paper. A minimum of four restoration alternatives were developed for each site, including the "no action" alternative. Ecological outcomes were assessed relative to habitat and connectivity metrics, and monetary costs were estimated following standard cost engineering and real estate methods.

Return-on-investment analyses were then undertaken to inform selection of one alternative at each site. Specifically, cost-effectiveness and incremental cost analyses (CEICA) provide a coupled set of techniques for comparing non-monetary benefits relative to monetary costs for a given level of output (Robinson et al. 1997, Deason et al. 2010). Cost-effectiveness analysis allows decision-makers to filter out which plans are most efficient at providing environmental benefits on a *per cost basis*. The incremental cost analysis is then conducted on the set of cost-effective plans to provide information on the change in cost between plans. This technique sequentially compares each plan to all higher cost plans to reveal changes in unit cost as output levels increase and eliminates plans that do not efficiently provide benefits on an *incremental unit cost basis*. Ultimately, this process resulted in a recommended restoration action at each of the nine sites on the Bronx River (See Baron et al. 2020 for details regarding all analyses).

The Bronx River drains a relatively small watershed (38.4 mi^2) with suburban upstream land use in Westchester County and intensively urban downstream land use in Bronx County. Social vulnerability indicators of the counties provide a stark contrast; for instance, Bronx County has 3 times more poverty, 2.5 times fewer doctors per capita, and 2.5 times greater rates of violent crimes than Westchester County (Data USA 2019). The challenge confronting the restoration planning team was to identify a portfolio of sites (i.e., a subset of the nine locations) that equitability distribute ecological benefits across these communities.

Although social equity encapsulates many factors, distributional aspect of restoration benefits were the focus of this analysis. We computed two proxies for equity at each restoration site: total population and classification as environmental justice communities. First, total population provides a simple metric for equitable allocation of benefits. For instance, all things being equal a restoration site with 1,000 potential users is preferred to a site with 10 potential users. A one-mile "halo" surrounding the project footprint was used to estimate population (Figure 2) with the assumption that residents within walking distance are the primary beneficiaries of the project. Total population was summed for any census block wholly or partially contained within this one-mile boundary (2010 Census data).

Second, adjacent communities were classified as Potential Environmental Justice Areas (PEJA). The New York State Department of Environmental Conservation (NYSDEC) identifies PEJAs as census block groups meeting one or more of the following criteria for urban areas (NYSDEC 2018): 51.1% or more of the population are members of minority groups or 23.59% or more of the population have incomes below the federal poverty level. Using the census blocks identified in total population calculations (Figure 2), we computed the population of minority residents (any group other than non-Hispanic White alone; Colby and Ortman 2015) and those with income less than the federal determination of poverty (US Census Bureau 2017). Data were summarized in the binary context of PEJA or non-PEJA based on the NYSDEC criteria.

This quantitative analysis of equity reveals striking differences among the nine restoration sites (Figure 3). The five sites in Bronx County all meet criteria as PEJAs and have large nearby populations (> 120,000 residents for all sites). Conversely, the Westchester County sites do not qualify as PEJAs and have substantially lower populations around 50,000 residents within one mile. These analyses provide important context for interpreting other restoration benefits related to ecological outcomes and monetary costs, and the equity metrics highlight apparent differences in sites for decision-makers.

These simple equity metrics were used in three formats to contextualize, inform, and communicate decision-making. First, population and PEJA status were presented to decision-makers as an independent set of information (Figure 3), which provided a general overview of the social context of the watershed. Second, equity metrics were shown alongside ecological outcomes and monetary costs in a "decision matrix" to display the trade-offs between project outcomes. Third, data were aggregated to communicate the benefits of watershed-scale portfolios of projects (i.e., combinations of sites). For instance, the recommended restoration plan ultimately included five sites, which reached over 680,000 nearby residents in three PEJAs. Although used indirectly in decision-making, the equitability of outcomes was critical context for decision-making regarding the ultimate selection of sites.

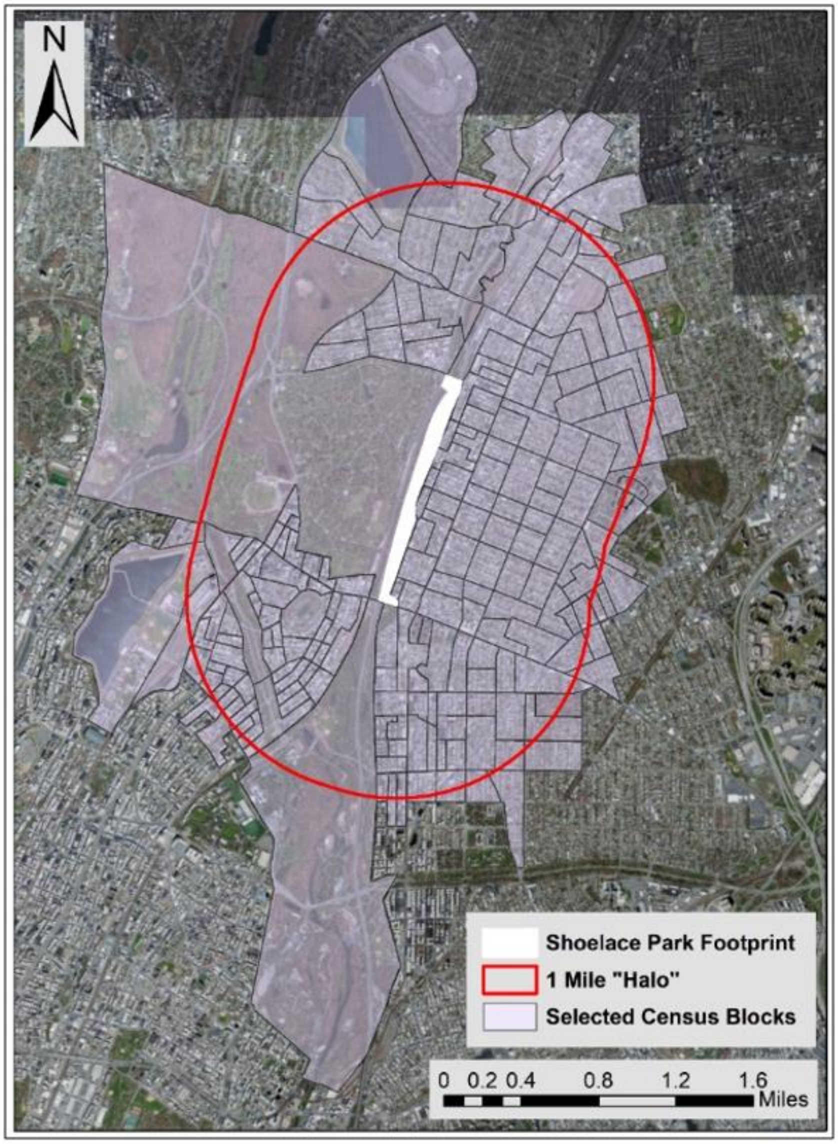

Figure 2. Environmental justice analysis on the Bronx River. Method of isolating a one-mile "halo" around Bronx River site for census estimates (e.g., Shoelace Park). White polygon indicates the project footprint, the red line brackets the one-mile assessment area, and grey outlines denote census blocks.

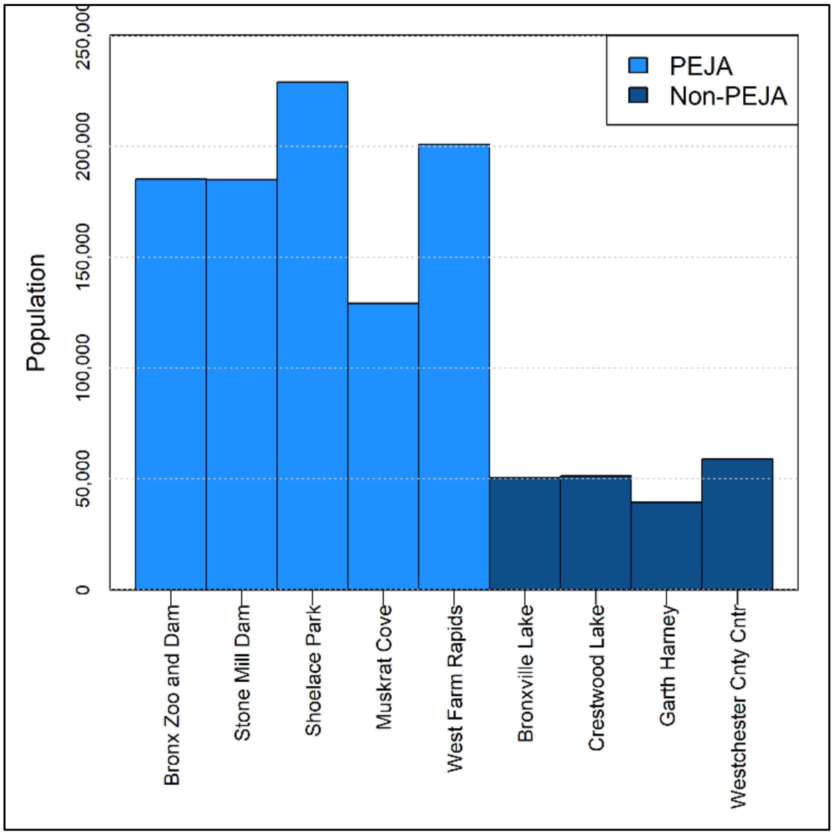

Figure 3. Results of environmental justice analysis on the Bronx River. Summary of equity-relevant metrics for the nine potential restoration sites. Sites are arrayed left-to-right from downstream to upstream. The five Bronx County sites (left) all meet criteria as PEJAs and have substantially larger populations than the four Westchester County sites (right).

Beargrass Creek, Louisville, Kentucky. Beargrass Creek in Louisville, Kentucky is a representative example of common urban stream management challenges. Three main branches drain this small watershed (~59 mi^2), where wetlands and forests were historically drained to support residential, commercial, and industrial land uses as the Louisville region grew. Some reaches were channelized to increase conveyance, and further geomorphic change occurred as a result of increased runoff from urban development. The USACE Louisville District and Louisville Metropolitan Sewer District are partnering to confront these challenges and identify actions to restore aquatic ecosystems in the watershed. The two primary ecological objectives of the projects are: (1) To reestablish quality and connectivity of riverine habitats and (2) To reestablish quality and connectivity of riparian habitats.

An initial array of 50+ potential restoration sites was identified based on prior watershed assessments, local knowledge, preliminary field scouting, and desktop geospatial analyses. These sites were screened relative to technical criteria as well as logistical, administrative, and policy factors, which ultimately resulted in 21 sites carried through for feasibility-level analysis. At each location, potential restoration actions were identified and combined into site-scale alternatives (4-25 alternatives per site depending on complexity, scale, and needs). Ecological outcomes were assessed relative to riverine and riparian habitat models, and monetary costs were estimated following standard cost engineering and real estate methods. CEICA was then conducted to identify a recommended action at each location. Ultimately, this process resulted in recommended ecosystem restoration actions at 14 sites (See Mattingly et al. 2021 for details regarding all analyses).

The recommendations at the 14 remaining sites were combined into 16,384 watershed plans (i.e., all possible combinations of sites). Ecological outcomes and monetary costs were computed for each plan as the sum of site-scale benefits and costs. These plans were again subjected to CEICA to identify efficient and effective portfolios of actions based on ecological outcomes. From this analysis, a watershed-scale plan including 12 restoration sites was identified. However, what watershed-scale plan would be identified if social outcomes like equity were taken into account?

An alternative decision logic was implemented at the watershed-scale to examine how recommendations would change if only social outcomes were used to inform decisions. Four categories of social outcomes were identified as pertinent to the project:

- *Logistics*: Social factors often inhibit the execution of restoration projects. This category addresses logistical factors that can slow down (or eliminate) restoration plans at a given location such as real estate constraints, construction access, and contaminated soils. While not strictly social "benefits", the absence of these social factors is crucial to restoration success.
- *Economic Effects*: This category addresses potential economic benefits associated with restoration such as a site's proximity to economic development corridors and employment opportunities. The effect of actions on flood levels were also incorporated into this category due to the potential for floods to inhibit economic development.
- *Social Outcomes*: This category assessed benefits of sites relative to community-oriented outcomes like visibility, equity, recreation and education, and stakeholder support.
- *Technical Significance for Budgeting*: USACE defines the “significance” of an ecosystem relative to institutional, public, and technical dimensions. Technical significance is also a crucial factor in determining the competitiveness of a USACE project in the national budgeting process. Two criteria for budget prioritization were adapted as a qualitative metric of site significance (EC-11-2-206, USACE 2014).

Each social outcome would ideally be assessed quantitatively using direct metrics or proxies, similar to the Bronx River analysis. However, time and resource constraints limited the capacity for a more quantitative analysis, and a qualitative approach was pursued. Each category was assessed using a consistent constructed scale of 0 to 20, where 0 is undesirable and 20 is desirable (Figure 4). Each metric was scored for the recommended alternative at the 14 remaining sites. The large project planning team scored the sites to try to incorporate multiple disciplinary perspectives as well as lived experiences and local knowledge of the watershed. The raw data were summed for each category and normalized from 0 to 1 for consistent comparison across categories. While a more empirical approach would be preferred (e.g., a stakeholder survey indicating community support), simple scoring systems can effectively distinguish outcomes and provide a basis for comparing disparate metrics.

Equity concerns are embedded directly and indirectly across this broad approach to social assessment. The environmental justice metric explicitly seeks to identify communities historically marginalized or overlooked (similarly to the Bronx River analysis without census using data). However, equity appears indirectly in other metrics as well. For instance, the employment metric could be considered a proxy for equality of economic opportunities, and the community support metric could be considered a metric of procedural equity.

Category	Sub-Category	Optimal 20 19 18 17 16	Suboptimal 15 14 13 12 11	Marginal 10 9 8 7 6	Poor 5 4 3 2 1
Logistical	Real Estate	All parcels owned by NFS	All parcels owned by NFS and public entity	Most parcels owned by public entity	Most parcels owned by private entity
	Access (constuctability)	Nearby public roadways and lands available to utilize for construction, no issues with topography	Topography is conducive to access but private properties surrounding	Topography is not ideal but access can be found in other ways, such as creating access roads that circumavigate steep terrain	Topography not conducive to good access, private property and obstructions
	HTRW issues	No known historical uses that may have contributed to contamination, very little uncertainty	No known historical uses that may have contributed to contamination, high levels of uncertainty	Known historical uses but resources for mitigation are present	Known historical uses that would have contributed to contamination
Economic	Employment	Ten or more businesses directly adjacent to stream	5-9 businesses directly adjacent to stream	1-4 businesses directly adjacent to stream	0 businesses directly adjacent to stream
	Potential	Located in accessible area with good visibility, nearby neighborhoods and businesses, restoration action will provide good potential for outdoor and paddlesport activities	Restoration action will provide good potential for outdoor and paddlesport activities but not accessible or visible	Accessible and visible but not a lot of opportuntiy for outdoor or paddlesport	Restoration action will not provide an opoortunity for paddlesport or outdoor activities, poor visibility and access
	Impact to local flooding	Vast improvement in flooding conditions based on H&H modeling	Slight improvement in flooding conditions based on H&H modeling	Flooding conditions stay the same based on H&H modeling	Flooding induction present based on H&H modeling
Social	Visibility	Good connecivity and accessibility to surrounding neighborhoods, included in other current plans with opportunity for aesthetic improvements	Some connections to surrounding neighborhoods but potential to improve, possibly included in current plans, aesethic improvement possible	Little accessibility to surrounding neighborhoods, little potential for improvement, not included in plans, aesthetic improvement unlikely	No accessibility from surrounding neighborhoods, little or no connection ro current plans, no aesthetic opportunity
	Environmental Justice	Located near low income or minority populations with little to no green infrastructure within 5 min walk	Located near low income or minority populations, very little green infrastrucutre within 5 min walk	No low income or minority populations present, some green infrastructure within 5 min walk	No low income or minority populations present, good network green infrastructure already within 5 min walk
	Recreation & Education	Predicted water quality improvements and points of access, adjacent to schools, churches, etc	Predicted some water quality improvements, some opportunity for points of access, schools, churches, etc nearby but not adjacent	Predicted minimal water quality improvements, very little opportunity for points of acces, schools, churches, etc nearby but not adjacent	No water quality improvements or potential to provide access points
	Community Support	Site specifically targeted at stakeholder and public meetings, broad interest across city	Some interest at public/ stakeholder meetings, surrounding neighborhood thinks project is important	Little interest a stakeholder/public meetings, some interest at neighborhood level	No interest at public/stakeholder meetings, no interest from local neighborhood
Technical	Scarcity	Habitat is extremely scarce, and restoration substantially reduces local scarcity (e.g., >50% over current reach condition).	Habitat is extremely scarce, and restoration reduces local scarcity (e.g., 25-50% over current reach condition).	Habitat is somewhat scarce, and project reduces local scarcity (e.g., 0-25% over current condition).	Habitat is common and/or project does not measurably reduce local scarcity.
	Connectivity	Makes critical direct physical connection between existing habitat areas or establishes a network of interconnected habitat.	Creates a nodal connection between existing habitat areas.	Restores suitability of existing connection. Expands area within corridor or home range.	Provides minor expansion to existing habitat.

Figure 4. Semi-quantitative system for assessing social outcomes in Beargrass Creek.

While simple, these metrics effectively distinguished sites across each category. For instance, logistical factors are generally more challenging at sites with many landowners, and economic development and social outcomes are generally highest at high profile sites in major parks and near downtown. Overall, these analyses indicate that some sites are consistently important relative to social outcomes. These metrics were combined into an overarching social metric and used to reassess the 16,384 watershed plans. CEICA was reconducted using only social outcomes to identify a general prioritization of sites relative to social benefits. Ultimately, these analyses helped interpret and contextualize the recommendation based solely on ecological outcomes. The social metrics also provided a useful conceptual tool for decision-makers to understand the relative benefits of different actions and communicate those benefits to the public.

LESSONS LEARNED

What then may be learned about the role of equity in informing urban stream management, and stream restoration specifically? This section qualitatively contrasts the case studies and seeks to identify general themes about operationalizing equity in water management decisions.

- *Equity is not the only social outcome*: As has long been recognized, equity of outcomes is an important issue in urban water management that can affect decision-making and help communicate project benefits (GWP 2016, McDermott et al. 2013, Montambault et al. 2018, Meerow et al. 2019, Langemeyer and Connolly 2020, Seigerman et al. *In review*). However, equity concerns are one of many social outcomes typically affected by urban water management. In the Beargrass Creek example, equity was embedded in a broader notion of societal benefits, but this approach has the potential to obscure any one outcome (e.g., equity) within a multi-metric index.

- *Being clear about what equity means in a given context*: Equity issues should be interpreted through the lens of a given project, region, and community, and there may be nuanced differences in what equity means at a given location. For instance, the Bronx River case study adopted a regulatory set of methods for classifying potential environmental justice areas based on income and race, whereas the Beargrass Creek project used a more qualitative notion of equity relative to environmental justice, jobs, flood damages, and community support.
- *A lack of metrics is not a problem*: A common misconception among engineers and natural scientists is that social processes defy quantification and few metrics exist. However, there are dozens of approaches for assessing equity in qualitative and quantitative terms (Kind et al. 2017, Seigerman et al. *In review*). In both projects, simple metrics were used to quantify equity, but even these crude metrics were extremely informative for project decision-making.
- *Site selection is an obvious application*: Equity concerns are easily displayed in site selection issues like the watershed-scale analyses in the Bronx River and Beargrass Creek. For instance, the population size of nearby residents is easily compared across the Bronx sites (Figure 3). However, equity issues extend beyond site selection and could engage site design choices, construction management, or operations (e.g., impacts of construction traffic or noise and up- vs. down-stream beneficiaries).
- *Uses of equity in decision-making can vary*: Equity metrics can be used in different formats to inform decisions. The Bronx River analysis focused on equity as a secondary outcome of restoration choices, whereas the Beargrass Creek study constructed an entire decision process based on social outcomes.
- *Distributional equity may be the "easy" part*: The case studies presented here show that distributional equity can easily be quantified and operationalized. However, neither project extensively incorporated procedural or recognitional issues. Exclusive attention to matters of distribution hinders the ability to understand and address the underlying causes of observed disparities (McDermott et al. 2013). The case studies presented are intended to demonstrate how equity can be easily operationalized in urban stream management, but these examples insufficiently address the broader importance of equity in project decision-making processes.

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