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Research article

Impacts of social indicators on assessing the recovery potential of impaired watersheds

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A B S T R A C T

An analysis was carried out to understand how watersheds' potential for restoration was impacted by social indicators. This study employed the USEPA Recovery Potential Screening tool, a decision support system, to compare 51 watersheds in the state of Mississippi, USA, using ecological, stressor, and social indices, and the recovery potential integrated (RPI) index. An in-depth analysis was performed on four watersheds in the Delta region of Mississippi (Lake Washington, Harris Bayou, Steele Bayou, and Coldwater River), each impaired by sediments and nutrients. Sixteen social indicators were categorized into three subcategories: Socio-Economic, Organizational, and Informational.

Watersheds with lower social indices had lower RPI scores. In the particular watersheds studied, the Socio-Economic subcategory was observed to be the most impactful to the overall recovery potential when compared to the other two social subcategories. As a sensitivity analysis, a "what if" simulation was performed to explore alternatives to upgrade a watershed's social index and, consequently, the relative recovery potential of the watershed to a target level. This analysis is useful for understanding how particular social indicators of a community impact the relative potential for recovering a watershed, beyond just the ecological and stressor conditions. It also sheds light on assessing which social indicators can be improved.

1. Introduction

Surface waters are adversely influenced by a wide variety of pollutants generated from human activities. When the water quality of a watershed is degraded to the point that it can no longer meet its water quality standards or designated uses—such as supporting fish and wildlife or recreation —it is listed as an impaired watershed. According to the U.S. Clean Water Act, section 303(d), impaired watersheds can be restored to ensure the continuation of their benefits for communities and natural aquatic environments (Clean Water Act, 1972). However, when a large number of watersheds is impaired in a given geographical area, the capacity of governing agencies to restore all of them at once is limited. Therefore, agencies need to develop a prioritized restoration schedule.

The concept of prioritizing watersheds for restoration has been developed and applied to a wide set of environmental problems. A method to prioritize watersheds based on their recovery potential, applicable for different environments and program goals, was explored by Norton et al. (2009). This approach is currently offered by the US Environmental Protection Agency (EPA) as a Recovery Potential Screening (RPS) Tool to compare watersheds in support of surface water quality management programs in states (USEPA, 2018a). The RPS Tool allows users to select indicators and weights relevant to a specific screening objective, generating a gradient of relative scores among the watersheds compared.

Other examples of water body prioritization include the work by Lin and Morefield (2011), who prioritized management options for coastal communities based on socio-economic, land use, and estuary condition indices. Several other studies prioritized water bodies using ecological and economic factors for the implementation of best management practices; an example is demonstrated by Jang et al. (2013). This approach prioritized watersheds to understand suites of agricultural best management practices for reducing sediment load. Jang et al. (2015) prioritized water bodies for conservation actions to reduce erosion and sedimentation. A similar

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study by Merovich et al. (2013) established priority sites for conservation by classifying watershed conditions into hierarchical spatial scales. Hall et al. (2014) established an ecological function and services approach for prioritizing water bodies for the development of total maximum daily loads for nonpoint source–related impairments. The prioritization approaches, as shown in the reviewed literature, focus on a holistic approach that considers the conditions of the human dimension and the biophysical environment.

The objective of this study was to understand the implications of how social indicators can affect the comparison and ranking of the impaired watersheds for recovery potential. This was studied using the RPS Tool and conducting an analysis of the impact of the selected social indicators.

2. Background

Decision-making on a large number of watersheds compared for their relative recovery potential is a multi-criteria process and is described in Norton et al. (2009) as needing a multi-metric index. There are several watershed features that indicate the likelihood of restoration success or a watershed's readiness for restoration action. These indicators can be used for prioritizing the recovery potential of impaired watersheds. The relevance of these indicators to recovery potential ranking can vary with the varying circumstances of impairments. For example, one might need to choose which watersheds are likely the most restorable from a particular impairment type; which watersheds are the most restorable based on a particular indicator; which watersheds might be significantly more difficult to restore; or which set of criteria can upgrade the relative recovery potential score of a watershed to the next level. This process involves a multi-criteria decision-making process, where the choices of alternatives are made using indicator values and their assigned weights as criteria. A multi-criteria decision analysis (MCDA) method enables users to select indicators and assign weights in a flexible manner for decision-making processes for problems involving multiple objectives (Mabin and Beattie, 2006). A decision on the multiple objectives is made by evaluating a number of alternatives that best fulfill the objectives.

Previous applications of MCDA in watershed-related areas include natural resource management (Mendoza and Martins, 2006), water resource planning and management (Hajkowicz and Collins, 2007), and environmental projects (Huang et al., 2011). The reviewed literature indicated the complexities of natural systems and noted the need to embrace the social, biophysical, and ecological issues to address the multiple concerns and the conflicting objectives of stakeholders. The MCDA methods in these references share the same theoretical approach, where the decision model is built on a set of criteria, a set of decision options, and a set of performance measures. The weighted summation algorithm was the most commonly used method, which is mathematically represented as Eq. (1).

$$S_i = \sum_{i=1}^{m} V_{i,j} W_j \quad (1)$$

where S_i is the overall performance score in a scale of −1 to 1, $V_{i,j}$ is the transformed performance score of a given criteria [i,j] on a scale of −1 to 1, and W_j are the weights that sum to 1.

To compare large numbers of water bodies and their watersheds, the RPS Tool was developed by using indicators within ecological, stressor, and social categories that influence the success of a restoration effort (USEPA, 2018b). The ecological category represents the biophysical condition and ability of a watershed to regain functionality. The stressor category reflects the disturbances to the watershed's condition from a variety of pollutant sources. The social category is related to the capacity of organizations and the condition of communities in a watershed's surrounding area linked to favoring activities that improve the quality of that water body. Social indicators are broad, and their subcategories include leadership, organization, and engagement; protective ownership or regulation; level of information, certainty, and planning; restoration cost, difficulty or complexity; socio-economic considerations; and human health, beneficial uses, recognition and incentives (USEPA, 2018b). The user's choice of indicators and their weights for a given restoration assessment depends on what is most appropriate to the watersheds being assessed, the availability of data, and the management objectives of the restoration. By measuring the same indicators on all watersheds of interest, an objective comparison can be performed. The recovery potentials are compared based on separate ecological, stressor, and social indices and the Recovery Potential Integrated (RPI) index that combines the indices of the three categories.

The focused analysis presented in this paper is on social indicators' impact on the recovery potential of a watershed, and we present here some background on the literature. The relationship between social indicators and quality of life (which is in part described by social indicators) of a region can relate to the opportunities that are provided to meet human needs in the forms of built, human, social, and natural capital, and the policy options that are available to enhance these opportunities (Costanza et al., 2006). Felce and Perry (1995) discussed five dimensions of quality of life: physical well-being, social well-being, material well-being, emotional well-being, and development and activity. The European Union defined the so-called '8 + 1' dimensions of quality of life: living condition, productivity, health, education, social interaction, economic and physical safety, governance and basic rights, natural and living environment, and overall life experience (European Union, 2015). Other studies attribute people themselves (mainly via socio-economic indicators), and the condition of the physical and the policy environments in which people live, as important domains of quality of life (Ferrans, 1990; Cella, 1994; Mandzuk and McMillan, 2005).

The numerical value assigned to each social indicator can vary among the surrounding communities of different watersheds. According to the EPA's research in developing the RPS Tool, social indicators can affect the recovery potential of a watershed. Therefore, it follows that if the values of a social indicator vary among watersheds, then recovery potential will also vary. Other examples of the relationship between environmental quality and well-being are documented in a literature review by Kamp et al. (2003). Case studies conducted by Pacione (2003) discussed that quality of life needs to be viewed in the geographical scale, and the problems associated with it should be addressed in a socio-spatial context. This is consistent with the RPS approach that recommends consideration of social metrics for comparing restoration potential across a range of geographically separate impaired watersheds.

3. Study area

This study first screened 51 watersheds at the 12-digit hydrologic unit code (HUC) subwatershed level, from different regions in the State of Mississippi, USA. Major water bodies included in these 51 watersheds were the Noxubee, Biloxi, Pearl, Little Tallahatchie, and Big Black Rivers and Pickwick Lake. The further in-depth analysis was narrowed to four impaired watersheds of elevated interest to the Mississippi Department of Environmental Quality (MDEQ) and located in the Yazoo River Basin, in the Delta region of Mississippi. These watersheds -Lake Washington, Harris Bayou,