Prioritizing the Restorability of Impaired Water Bodies: A Case Study of Four Watersheds in the Delta Region in the State of Mississippi

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The restorability potentials of four impaired water bodies (Lake Washington, Harris Bayou, Coldwater River, and Steele Bayou) in the Delta region of Mississippi were compared in this study using the EPA Recovery Potential Screening (RPS) tool. A variety of selected indicators under ecological, stressor, and social fields were used. Each of the studied water body's restorability potential was ranked based on the most influential indicator score, the summary index scores of the three fields, and the integrated recovery potential (IRP) score of the three fields. Restorability scores were calculated using two scenarios: (1) with indicators assigned with equal weights and (2) with indicators assigned with unequal weights.

Agricultural activity, covering 65 to 80% of the total land use of the four water bodies, was found as the most stressful single indicator. In that regard, Harris Bayou was determined to be the most difficult to restore. Based on the summary index scores, Steele Bayou and Lake Washington were determined to have the most and the least favorable biophysical conditions for restorability, respectively. The Coldwater River was determined to have the highest social capacity for restorability. The water bodies were also compared based on an overall integrated recovery potential (IRP) score of the three fields. Coldwater River and Steele Bayou were found as the first and second most restorable water bodies in both the equally and unequally weighted scenarios. Harris Bayou and Lake Washington were ranked as third and fourth, respectively, in the equally weighted scenarios, and fourth and third, respectively, in the unequally weighted scenarios. A remarkable rank change between Harris Bayou and Lake Washington in the unequally weighted scenario implies the sensitivity of restorability potential score to the assigned indicator weight. Based on this rationale, this research suggests further study on the EPA RPS tool to understand the sensitivity of the restorability potential based on indicator weights.

Introduction

Water bodies not meeting their designated use are listed as impaired as stated by Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The Mississippi Department of Environmental Quality (MDEQ) has identified several impaired water segments in the state of Mississippi. To ensure the continuation of the community and environmental benefits of the state water resources, agencies are charged to restore the quality of impaired water bodies. All the identified impaired water bodies cannot be restored at one time due to the limited capacity of agencies in charge. Therefore, it is important to set a prioritized restoration plan.

This study conducted a recovery potential screening of four water bodies deemed important in the Yazoo Basin of Mississippi: Lake Washington, Harris Bayou, Coldwater River, and Steele Bayou (Figure 1). The major impairments in these water bodies are sediments and nutrients, which are harmful to fish and wildlife. This screening was aimed at comparing the four water bodies in order to determine the best candidate for restoration and re-attainment of water quality standards.

Methodology

The US EPA has developed a technical assistance tool known as the Recovery Potential Screening (RPS). This tool is aimed at assisting states to consider where to invest their efforts for a greater likelihood of success, based on the traits of their own geographic area's environment and communities. A summary of the USEPA RPS approach is presented in Figure 2.

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The watersheds of the four waters are already mapped GIS datasets by the United States Geological Survey (USGS). Compilation of the data required for screening and analysis of the results was performed on the basis of existing geospatial units.

Indicator selection and measurement:
The RPS tool demonstrated more than 200 metrics that likely indicate the success of a restoration effort. The recovery potentials of the four water bodies were compared using measurable ecological, social, and stressor metrics. Candidate indicators were selected based on their relation to nutrient and sediment impairments and availability of data for all watersheds (Table 1). The selected indicators were measured both quantitatively and qualitatively. The equivalent quantitative values of qualitatively described indicators were inferred from the supporting literature. A higher value of ecological and social indicators implies a better recovery potential. A higher stressor indicator is associated with a lower recovery potential.

Weight assignment:
Equal and unequal weights were assigned to selected indicators (Table 2). Equal weights were assigned with an assumption that all selected indicators have an equal level of relevance to the success of a restoration effort. However, in practice, different indicators would likely have different levels of relevance to a restoration effort for sediment and nutrient impaired waters. To account for this, we assigned different weights for additional scenarios based on the amount of literature supporting the relation between the indicator and its relation to restoration.

Table 1. Indicators used for recovery potential ranking of the four water bodies

Ecological Field		**Stressor Field**		**Social Field**	
Indicator	**Code**	**Indicator**	**Code**	**Indicator**	**Code**
Natural land cover (%)	Eco1	Agriculture land cover (%)	Stressor1	Population size	Social1
Forest land cover (%)	Eco2	Urban land cover (%)	Stressor2	TMDL or other plan existence	Social2
Wetland land cover (%)	Eco3	Aquatic barriers	Stressor3	Recreational resource	Social3
Number of impairments	Eco4	Seasonal relative water level change	Stressor4	High school graduates, 2008-12	Social4
Approximate watershed shape	Eco5			Bachelor's degrees, 2008-12	Social5
Watershed size	Eco6			Persons below poverty level, 2008-2012	Social6
				Non-employer establishments, 2012	Social7
				Land area in square miles, 2010	Social8
				Persons per square mile, 2010	Social9

Table 2. Weights assigned for equally (shown in column labeled as "Equal") and unequal (shown in column labeled as "Unequal") weighted scenario

	Weight		Weight		Weight		Weight	
Indicator	**Equal**	**Unequal**	**Indicator**	**Equal**	**Unequal**	**Indicator**	**Equal**	**Unequal**
Eco1	1	2	Stressor1	1	2	Social1	1	1
Eco2	1	2	Stressor2	1	2	Social2	1	1
Eco3	1	1	Stressor3	1	1	Social3	1	1
Eco4	1	1	Stressor4	1	1	Social4	1	1
Eco5	1	1.5				Social5	1	1.5
Eco6	1	1.5				Social6	1	1
						Social7	1	1
						Social8	1	1
						Social9	1	1

Results and Discussion

The results of these screening calculations were compared based on the most influential indicator score, summary index scores, and integrated recovery potential (IRP) scores.

Ranking based on influential indicator score:

The percent of the agricultural land cover was selected as the most influential indicator because of the following reasons. Excess nutrients and sediments are related to agricultural activities. The RPS tool supports this rationale with more than 70 documents (the maximum amount of literature support compared to other indicators). Streams and lakes throughout the state of Mississippi are receiving excessive amounts of nutrients and sediments from agricultural land. This is due to the higher percent of the agricultural land use of the four watersheds, covering 65 to 80 percent of the total land. Therefore, the restoration efforts of these water bodies are likely most influenced by agricultural activities. According to this single index (agricultural land use) ranking, Coldwater River, Lake Washington, Steele Bayou, and Harris Bayou are ranked as having the most to least potential for restorability, respectively (Table 3).

Rank based on ecological, stressor, and social summary index scores:

This approach clusters indicators as a summary index within each field (ecological, stressor, or social context) and ranks waters using the corresponding comparative values. This kind of analysis enables the focus on one individual field, without considering the two other fields. For the sake of this analysis, the ecological and stressor fields were classified as condition-based indicators. Condition-based denotes the biophysical factors that strengthen the restorability capacity (ecological) or that stress the restorability capacity (stressor). A community-based restorability capacity represents the social conditions desirable for restoration success.

A 3D bubble plot of summary indices was used to demonstrate the community-based and condition-based capacities (Figure 3a for equally weighted and Figure 3b for unequally weighted scenarios). A higher ecological and social index and a lower stressor index scores mean a higher recovery potential or a favorable biophysical condition and community capacity. The upper-left quadrant of the 3D

Table 3. Ranking based on the single most influential indicator (agricultural land cover)

	Lake Washington	Harris Bayou	Coldwater River	Steele Bayou
Agricultural land cover (%)	69	79.39	67.1	71.5
Restorability rank	2	4	1	3

bubble plot (higher ecological potential with lower stressor indices) holds a subset of watersheds of higher restorability. None of the four water bodies' summary scores fall in the upper-left quadrant. Steele Bayou and Lake Washington were located in the upper-right quadrant, which implies relatively higher restorability in the context of the ecological index and relatively lower restorability in the context of the stressor index. Coldwater River and Harris Bayou were located in the lower-left quadrant with lower restorability in the context of the ecological index and higher restorability in the context of the lower stressing index. The upper-right and lower-left quadrants were further compared in the context of the social summary index, represented by the size of the bubble. Coldwater River had the highest social index score, followed by Steele Bayou, Lake Washington, and Harris Bayou, respectively.

The summary index scores for equally and unequally weighted scenarios were also separately compared using a 3D bubble plot. When more weight was assigned to land use indicators, the Coldwater River location moved slightly to the upper-left quadrant, which implied that its ecological restorability capacity was increased. However, the high agricultural land cover made Harris Bayou and Steele Bayou more stressed than they were in the equally weighted scenario.

Rank based on integrated recovery potential (IRP) scores:

This approach ranks each of the four water body's recovery potential from highest to lowest based on their IRP scores. The three summary indices were aggregated to the IRP scores (Figure 4). Based on the IRP scores, Coldwater River had the highest restorability potential in both equally and unequally weighted scenarios. Although it was ranked first in both scenarios, the restorability capacity remarkably decreased from 2.74 in equally weighted to 2.26 in unequally weighted. The decrease in score is due to more stress associated with the assigned double weight on the percent of agricultural land cover. From this result, it is possible to conclude that the restorability score is more sensitive to stressor index than ecological and social indices. Steele Bayou was ranked as the second most restorable water body, and the scores were approximately the same in both the equally and the unequally weighted scenarios. A remarkable ranking change was observed between Harris Bayou and Lake Washington when unequal weights were assigned. As stated earlier, Harris Bayou had the lowest restorability rank based on the agricultural land cover. Therefore, the assigned double weight in the unequally weighted scenario added a double stressor to Harris Bayou's restorability and decreased its RPI score from 1.56 to 1.39 and its rank from 3 to 4.

Conclusions

This study demonstrated how the recovery potentials of water bodies with common impairment types (nutrients and sediments) can be prioritized. The relative recovery potential scores were used to understand how the water bodies differ in restorability. From a single indicator index ranking, it was possible to identify an indicator that is potentially stressful to restoration. A summary index of the ecological, stressor, and social fields indicate the biophysical and community conditions of a watershed for a success of a restoration effort. A higher ecological and a lower stressor index mean a favorable biophysical condition for restoration. A higher social summary score also implies a better community capacity. Indicator weights have significant effects on recovery potential ranking. This study suggests further study to understand the relative relevance of each indicator to a given restoration effort.

References

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2. US Environmental Protection Agency (2012). Recovery Potential screening tool. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/recovery/index.cfm. Accessed 20 August 2014

Acknowledgement

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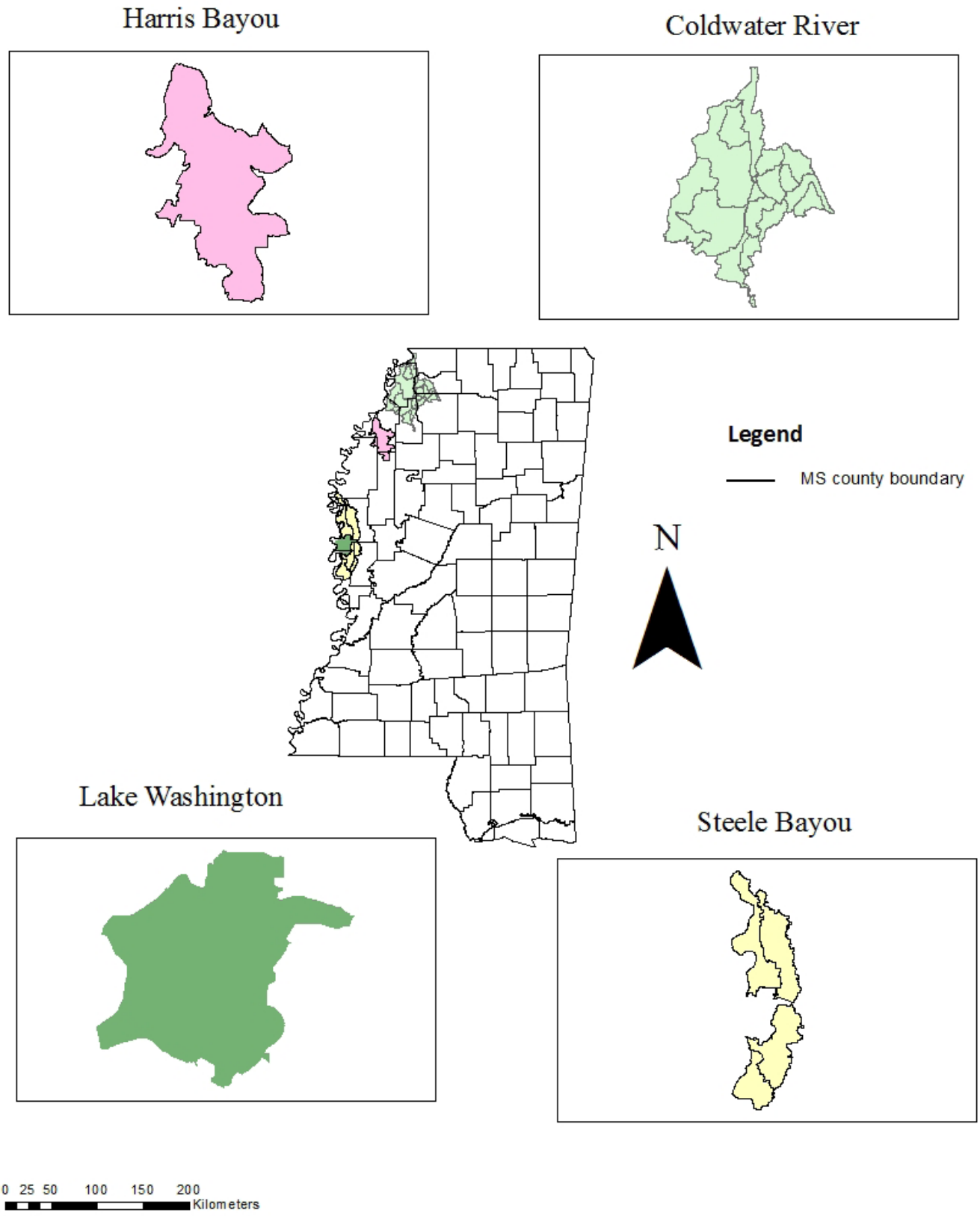

Figure 1. Watershed boundaries of the four studied water bodies in the Delta region of Mississippi.

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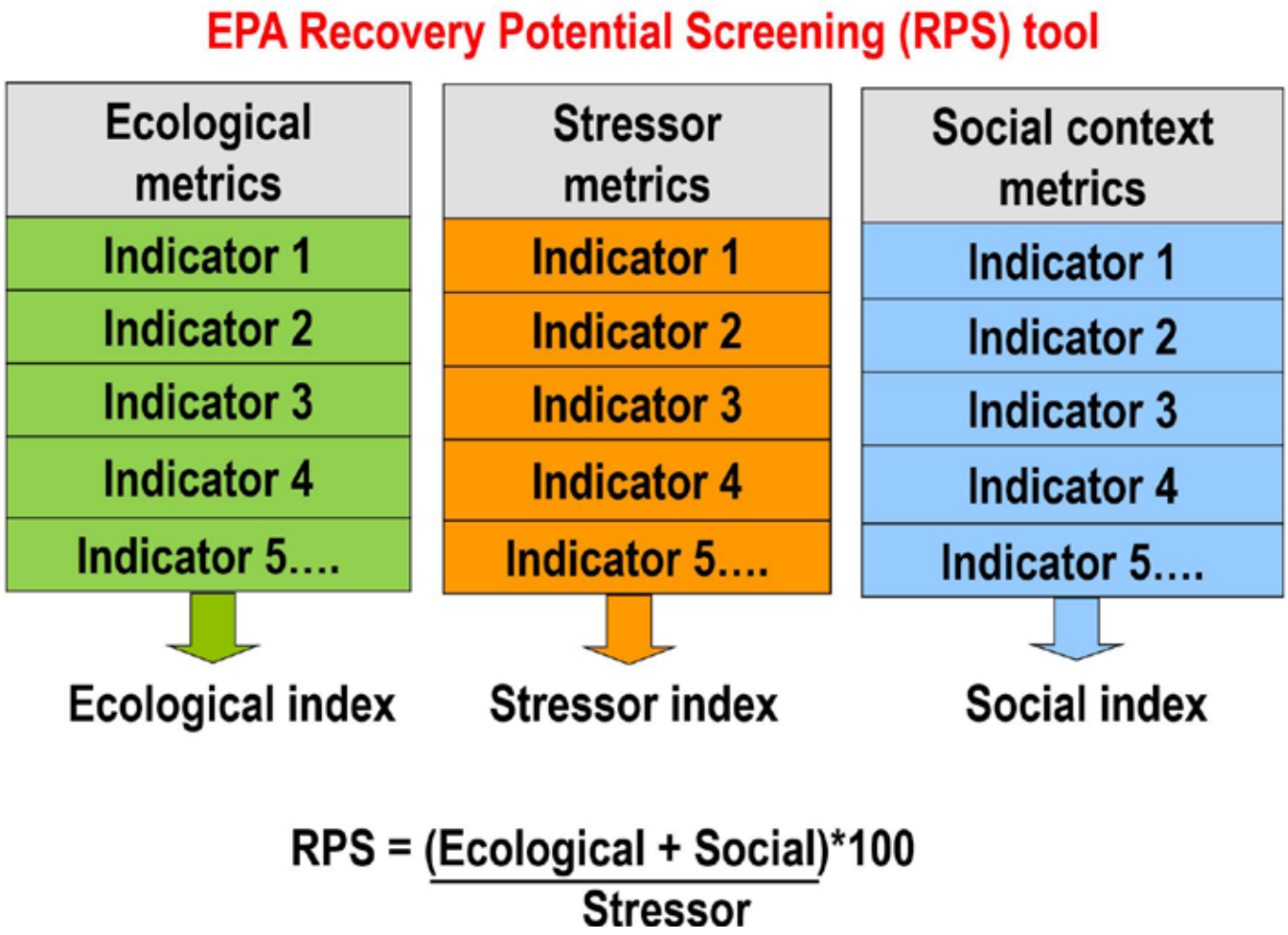

Figure 2. A basic approach of the USEPA recovery potential ranking. Metrics represents indicators under each field.

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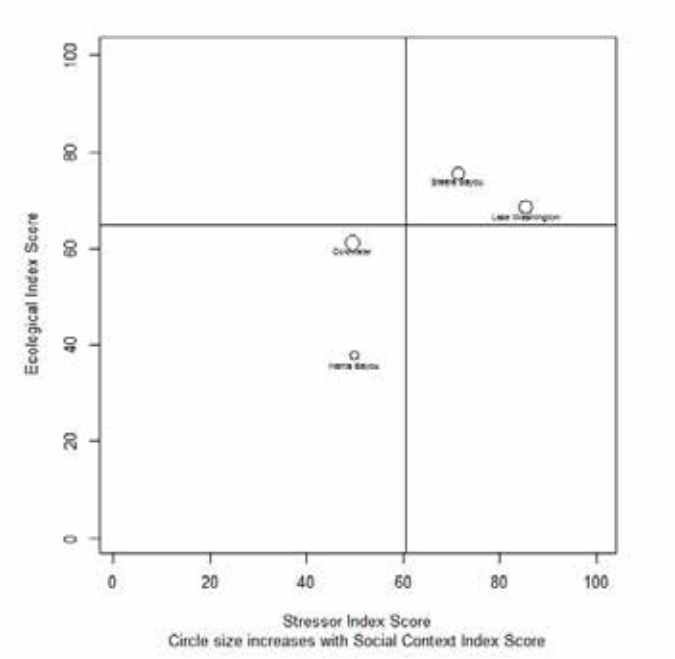
a.



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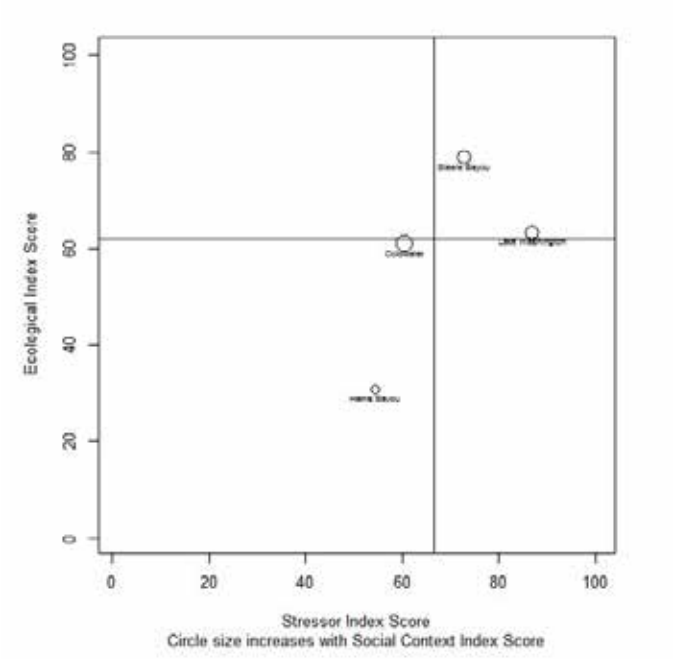

Figure 3a. A 3D bubble plot of summary indices for equally weighted scenario.

Figure 3b. A 3D bubble plot of summary indices for unequally weighted scenario.

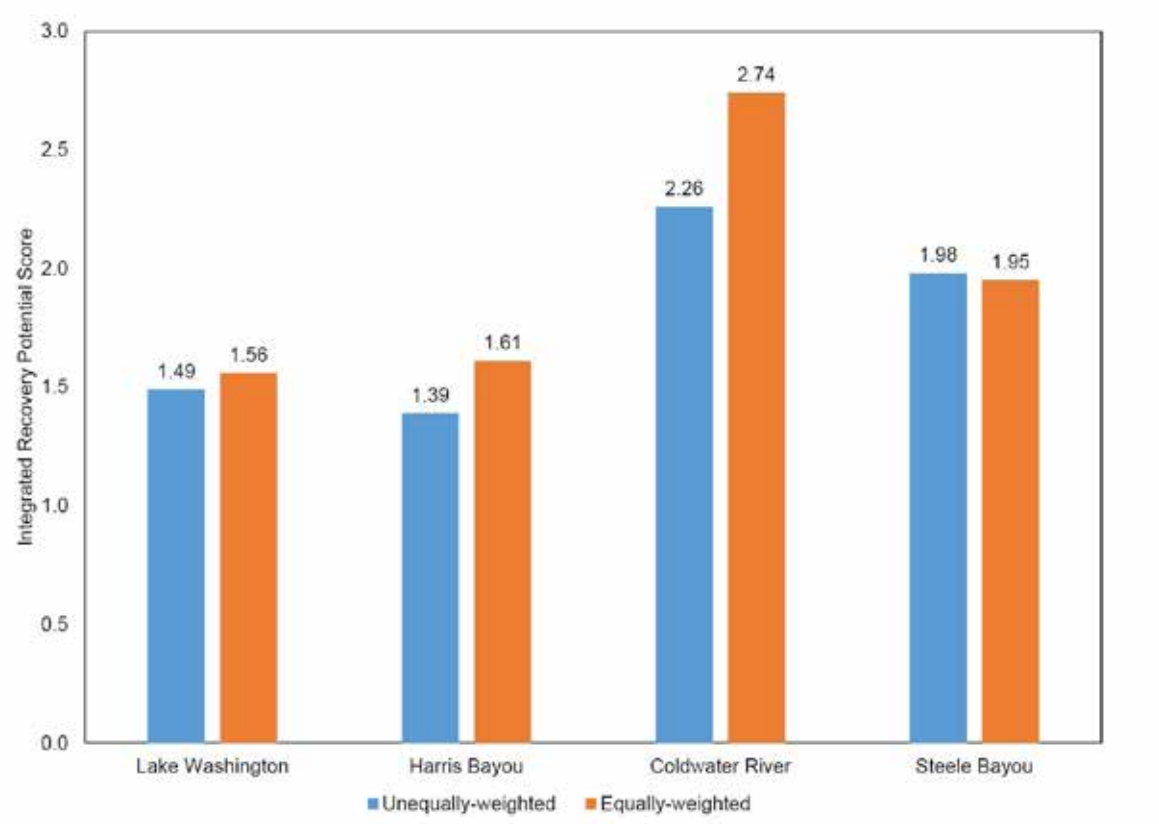

Figure 4. Integrated Recovery Potential scores for equally weighted and unequally weighted scenarios.