Methodology of socio-environmental report cards for the Clinton, Detroit, Huron, River Raisin, and Rouge Rivers

Methods report on data sources, calculations, and additional discussion

August 16, 2024

Project Team

This project was developed and produced by the University of Maryland Center for Environmental Science (UMCES) Integration and Application Network (IAN). Council Fire, LLC, consulted on the development of economic indicators. Funding for this project was provided by the Fred A. and Barbara M. Erb Family Foundation.

UMCES: Annie Carew, João Coimbra, Bill Dennison, Joe Edgerton, Anikka Fife, Ann Foo, Alexandra Fries, S. Conor Keitzer, Heath Kelsey, Nathan Miller, Lorena Villanueva-Almanza

Council Fire: Michael Shuman, George Chmael II

Table of Contents

Socio-Environmental Report Cards: A Holistic Assessment of the Human and Natural Environment

Goals and Objectives

The goal of this project was to help local watershed groups and their stakeholders create assessments of healthy and sustainable rivers and communities in southeastern Michigan. To assess the environmental, social, and economic conditions of southeastern Michigan, UMCES co-developed socio-environmental report cards with the Clinton River Watershed Council, Friends of the Detroit River, Huron River Watershed Council, River Raisin Watershed Council, and Friends of the Rouge. Six report cards were created: one for each watershed and an overall report card for Southeast Michigan. The process of developing the report cards and the resulting information:

1. Creates a shared vision for a healthy and sustainable Southeast Michigan.
2. Improves understanding and raise awareness about socio-environmental conditions.
3. Increases collaboration and strengthen relationships among stakeholder groups.
4. Improves engagement in the decision-making process through clear messaging.

Watershed Information

The watersheds included in this project were the Clinton, Detroit, Huron, River Raisin, and Rouge rivers (Figure 1). Combined, these watersheds cover 3,410 mi^2 (8,837 km^2), contain over 3,700 mi (6,000 km) of streams and rivers, and are home to nearly 4 million people. About 42% of the watershed is developed, 13% is forested, 31% is farmland, and 11% is wetlands.

Southeast Michigan is a hub for business and industry in the region, with much of the original growth and prosperity concentrated around the automobile industry in Detroit. More recently, the economy is diversifying as the area recovers from economic depression and a long history of environmental degradation and social problems. Healthy and sustainable watersheds and communities will play a key role in southeast Michigan's recovery and future prosperity.

Watershed boundaries were developed through discussions with watershed groups to accurately capture their areas of focus for this project, so may differ slightly from traditional watershed boundaries.

Figure 1. Watershed boundaries of the five rivers of Southeast Michigan that were included in this project, along with major rivers and tributaries, metropolitan areas, and county lines.

The **Clinton River** watershed drains a 760 mi^2 (1,968 km^2) area and is home to ~1.29 million people. A large portion of the Clinton is dominated by human uses, with about 55% of the watershed developed and 18% in agricultural production. Forests (13%) and wetlands (10%) also occur throughout the watershed.

The **Detroit River** watershed includes smaller tributaries that drain directly into the river, including Ecorse Creek, and is entirely within Wayne County. While the Detroit is the smallest watershed (198 mi^2 or 510 km^2), with around 475,000 residents, it is one of the most densely populated. This watershed is highly urbanized (77% developed). Natural areas do exist, with nearly 10% of watershed forested or wetlands. Small-scale agriculture is also present, with about 3% of the watershed considered farmland. Most of the non-urban land uses are concentrated in the southwestern portion of the watershed.

The **Huron River** watershed is the second largest in the region (918 mi^2 or 2,379 km^2). Land use in this watershed is fairly evenly distributed among developed areas (34%), forests (20%), farmland (22%), and wetlands (19%). The Huron River provides the majority of Ann Arbor's drinking water and is home to about 627,000 people.

While the **River Raisin** watershed is the largest in the region (1,060 mi^2 or 2,745 km^2), it is the most sparsely populated, with ~181,000 people. Agriculture is the most prevalent land use, covering ~66% of the area, and is the economic and cultural backbone of communities in the watershed. About 12% of the watershed is developed, with smaller patches of forests (10%) and wetlands (10%) spread throughout.

The **Rouge River** watershed drains a 467 mi^2 (1,210 km^2) area and is home to over 1.35 million people. This highly urbanized watershed (85%) does contain fragmented forested land (6%), farmland (4%), and wetlands (3.1%), mostly in its upper reaches or in urban green spaces.

Co-Development Process

The University of Maryland Center for Environmental Science Integration and Application Network (UMCES IAN) partnered with Council Fire, LLC, the Clinton River Watershed Council, Friends of the Detroit River, Huron River Watershed Council, River Raisin Watershed Council, and Friends of the Rouge to co-create socio-environmental reports cards for five rivers in Southeast Michigan and one overall report card for the whole region. A series of workshops occurred on November 4, 10, and 16, 2021. Because of the COVID-19 global pandemic, these workshops were held virtually. Nearly 60 stakeholders from all watersheds participated in these workshops to 1) identify shared values, threats, and priorities, 2) propose indicators, and 3) identify data sources and expertise. Following these initial workshops, UMCES IAN met with members of each watershed group to narrow down the list of indicators and to identify metrics and sources of data.

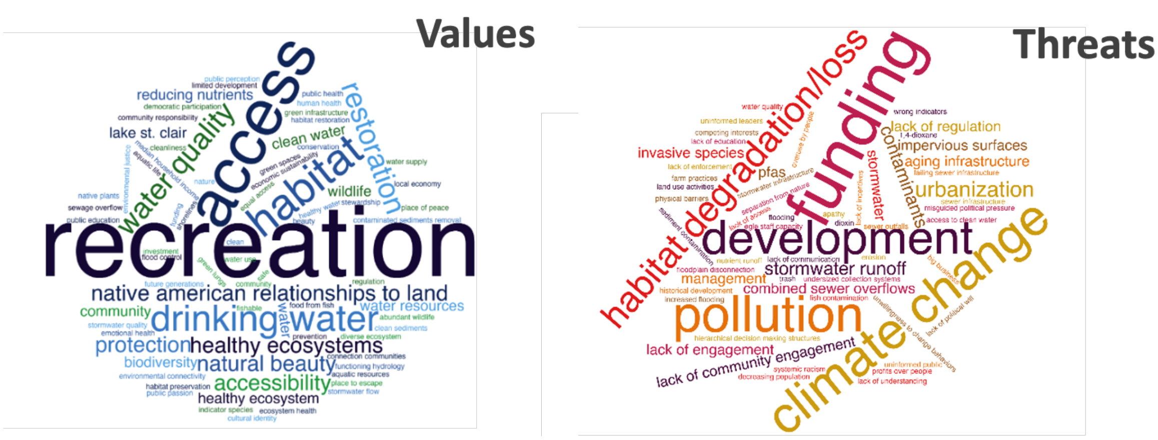

Figure 2. Values and threats identified during stakeholder workshops.

The UMCES team obtained and evaluated data availability for each proposed indicator. This included many virtual meetings to determine data sources, identify data gaps, and establish thresholds for scoring. Once UMCES IAN calculated draft scores, UMCES IAN and Council Fire met with all the watershed groups to discuss preliminary results in January and February 2023. Feedback from the watershed groups was used to finalize indicator scores. UMCES IAN met with each watershed group individually in February, March, and April 2023 to discuss final scores and brainstorm story ideas for each group's report card and the overall regional report card. UMCES IAN then created the report card layouts while the watershed groups wrote the stories and provided the images.

The indicators used in this report card assessed what stakeholders value about their watersheds and threats to those values (Fig. 3). The indicators reflect the shared perspective of the five watershed organizations, UMCES's experience in developing report cards, and Council Fire's experience evaluating economic conditions, and numerous local stakeholders in the southeast Michigan region. The initial list of indicators was evaluated for data quality and availability, the presence of meaningful goals, and relevancy for assessing sustainable watersheds and communities in southeast Michigan. The final set of 33 indicators assessed various aspects of the human and natural environment and were grouped into categories of economic (Economy), social (Human Health, Infrastructure, and Recreation), and environmental (Ecosystem and Water Quality).

Economy indicators included the cost of flooding, income equality, household income, local ownership, river economy, and trade. Ecosystem indicators included bird diversity, benthic community, forests, protected lands, tree cover, and wetlands. Human health indicators included air quality, bacteria, environmental justice, fish consumption, and heat vulnerability. Infrastructure indicators included affordable housing, farmland, flooding, impervious surfaces, and sewer overflows. Recreation indicators included beach access, fishing, parks, walkability, and watercraft access. Water quality indicators included dissolved oxygen, nitrogen, phosphorus, turbidity, and water temperature.

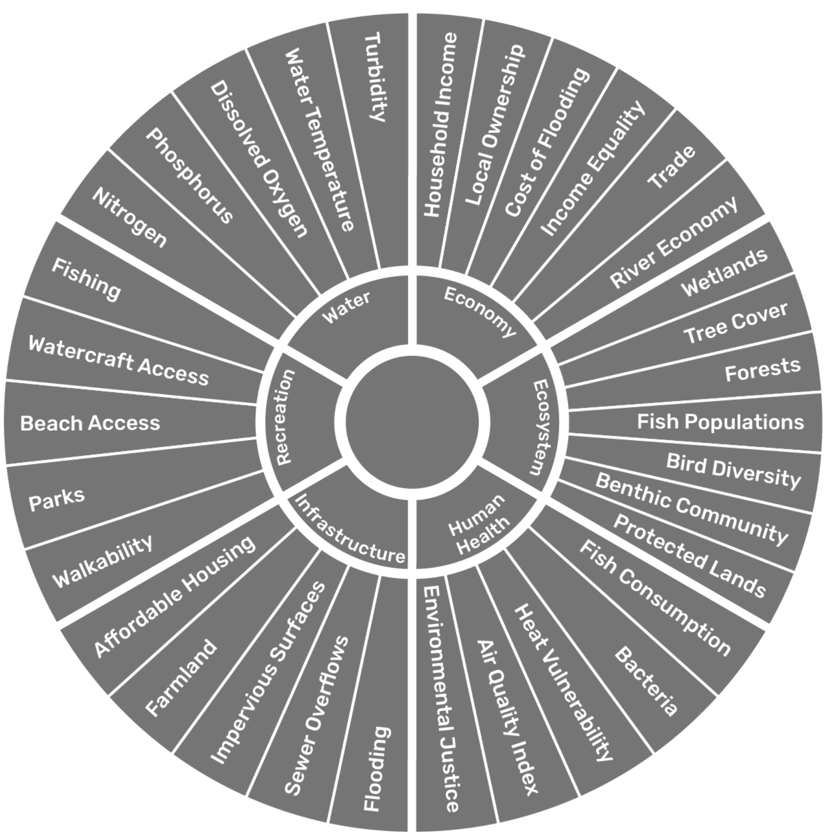

Figure 3. A “pie wheel” diagram that illustrates how the 33 indicators were divided into categories for assessment.

Thresholds, Scoring, and Weighting Schemes

This section provides a general overview of how thresholds were identified and indicators scored to aid in the development of future indicators and report cards. Once the indicators were identified, targets or thresholds for each indicator were developed. Establishing targets for each indicator can be done by using pre-existing standard thresholds from the scientific literature, or by determining acceptable management goals. Ideally, a threshold indicates a tipping point where current knowledge predicts an abrupt change in an aspect or some aspects of conditions. Thus, from the perspective of choosing meaningful, condition-related thresholds, this must be the point beyond which prolonged exposure to unhealthful conditions elicits a negative outcome for environmental or human health. For example, prolonged exposure to low dissolved oxygen concentrations can harm or kill aquatic organisms, disrupting aquatic ecosystems.

Thresholds represent an agreed-upon value or range of values outside of which an ecosystem, including both the human and natural environment, moves away from a desired state and toward an undesirable state. Because many managed ecosystems have multiple and broad-scale stressors, thresholds can also be viewed as representing the level of impairment that an environment can sustain before resulting in significant, perhaps irreversible, damage. Often, chosen indicators already have established thresholds. A good place to start looking for existing thresholds and goals is in other report card methods or scientific reports and publications.

If no thresholds exist, new thresholds can be related to management goals, which can be used to guide the selection of appropriate indicators. Even with the definition of agreed-upon thresholds, there is still the question of how best to use thresholds in management and governance. Regardless, thresholds can be effectively used to track socio-environmental change and define achievable management goals for the restoration, preservation, and conservation of a system. As long as threshold values are clearly defined and justified, they can be updated in light of new research or management goals and, therefore, provide a focus for the discussion and implementation of management. Alternatively, if stressors are correctly identified, there should be multiple attributes (indicators) of the region that discriminate in predictable and significant ways between the least and most impaired conditions. Reference areas can then be characterized using these data, which can be used to develop threshold values. To determine thresholds for Southeast Michigan watersheds, working groups of scientific and management experts were engaged.

Once thresholds were identified, data were scored using either a pass/fail or multiple-threshold method. When possible, multiple thresholds were used to provide a gradation of results from very poor to very good, rather than just pass or fail, but this was not appropriate or possible for all indicators.

A pass/fail scoring method is a simple method used to calculate indicator scores based on whether or not a relevant threshold was met. The process outlined below uses total phosphorus as an example, and results are scored on a scale of 0 to 100%, where the higher percentage values represent more healthy conditions (Fig. 4).

1. Sort data by station.

Region	Site	Date	TP (mg/L)
1	ON02GD9041	01/23/18	0.519
1	ON02GD9041	02/21/18	0.312
1	ON02GD9041	02/28/18	0.0439
1	ON02GD9041	03/21/18	0.0143
1	ON02GD9041	04/03/18	0.0141
1	ON02GD9041	04/17/18	0.0813
1	ON02GD9041	05/01/18	0.0215
1	ON02GD9041	05/15/18	0.074
1	ON02GD9041	05/30/18	0.0617
1	ON02GD9041	06/26/18	0.0929
1	ON02GD9041	07/17/18	0.134
1	ON02GD9041	07/31/18	0.0559
1	ON02GD9041	08/14/18	0.0461
1	ON02GD9041	08/28/18	0.0745
1	ON02GD9041	09/11/18	0.0581
1	ON02GD9041	09/25/18	0.0518
1	ON02GD9041	10/09/18	0.0563
1	ON02GD9041	10/23/18	0.0253
1	ON02GD9048	01/23/18	0.105
1	ON02GD9048	02/21/18	0.34
1	ON02GD9048	02/28/18	0.107
1	ON02GD9048	03/21/18	0.0212
1	ON02GD9048	04/03/18	0.0625
1	ON02GD9048	04/17/18	0.0885
1	ON02GD9048	05/01/18	0.0688
1	ON02GD9048	05/15/18	0.0545
1	ON02GD9048	05/30/18	0.0353
1	ON02GD9048	06/26/18	0.0775
1	ON02GD9048	07/17/18	0.102
1	ON02GD9048	07/31/18	0.0609
1	ON02GD9048	08/14/18	0.0825
1	ON02GD9048	08/28/18	0.0605
1	ON02GD9048	09/11/18	0.0759
1	ON02GD9048	09/25/18	0.0537
1	ON02GD9048	10/09/18	0.0501
1	ON02GD9048	10/23/18	0.0266

2. Calculate the score for each data point. Ex: If TP<0.07625 mg/l, the score = pass (or 100).

Region	Site	Date	TP (mg/L)	Threshold	TP Score
1	ON02GD9041	01/23/18	0.519	0.07625	0
1	ON02GD9041	02/21/18	0.312	0.07625	0
1	ON02GD9041	02/28/18	0.0439	0.07625	100
1	ON02GD9041	03/21/18	0.0143	0.07625	100
1	ON02GD9041	04/03/18	0.0141	0.07625	100
1	ON02GD9041	04/17/18	0.0813	0.07625	0
1	ON02GD9041	05/01/18	0.0215	0.07625	100
1	ON02GD9041	05/15/18	0.074	0.07625	100
1	ON02GD9041	05/30/18	0.0617	0.07625	100
1	ON02GD9041	06/26/18	0.0929	0.07625	0
1	ON02GD9041	07/17/18	0.134	0.07625	0
1	ON02GD9041	07/31/18	0.0559	0.07625	100
1	ON02GD9041	08/14/18	0.0461	0.07625	100
1	ON02GD9041	08/28/18	0.0745	0.07625	100
1	ON02GD9041	09/11/18	0.0581	0.07625	100
1	ON02GD9041	09/25/18	0.0518	0.07625	100
1	ON02GD9041	10/09/18	0.0563	0.07625	100
1	ON02GD9041	10/23/18	0.0253	0.07625	100
1	ON02GD9048	01/23/18	0.105	0.07625	0
1	ON02GD9048	02/21/18	0.34	0.07625	0
1	ON02GD9048	02/28/18	0.107	0.07625	0
1	ON02GD9048	03/21/18	0.0212	0.07625	100
1	ON02GD9048	04/03/18	0.0625	0.07625	100
1	ON02GD9048	04/17/18	0.0885	0.07625	0
1	ON02GD9048	05/01/18	0.0688	0.07625	100
1	ON02GD9048	05/15/18	0.0545	0.07625	100
1	ON02GD9048	05/30/18	0.0353	0.07625	100
1	ON02GD9048	06/26/18	0.0775	0.07625	0
1	ON02GD9048	07/17/18	0.102	0.07625	0
1	ON02GD9048	07/31/18	0.0609	0.07625	100
1	ON02GD9048	08/14/18	0.0825	0.07625	0
1	ON02GD9048	08/28/18	0.0605	0.07625	100
1	ON02GD9048	09/11/18	0.0759	0.07625	100
1	ON02GD9048	09/25/18	0.0537	0.07625	100
1	ON02GD9048	10/09/18	0.0501	0.07625	100
1	ON02GD9048	10/23/18	0.0266	0.07625	100

3. Calculate the score for each site by averaging the scores for each data point in that site.

Region	Site	Date	TP (mg/L)	Threshold	TP Score	Site Scores
1	ON02GD9041	01/23/18	0.519	0.07625	0	72
1	ON02GD9041	02/21/18	0.312	0.07625	0	
1	ON02GD9041	02/28/18	0.0439	0.07625	100	
1	ON02GD9041	03/21/18	0.0143	0.07625	100	
1	ON02GD9041	04/03/18	0.0141	0.07625	100	
1	ON02GD9041	04/17/18	0.0813	0.07625	0	
1	ON02GD9041	05/01/18	0.0215	0.07625	100	
1	ON02GD9041	05/15/18	0.074	0.07625	100	
1	ON02GD9041	05/30/18	0.0617	0.07625	100	
1	ON02GD9041	06/26/18	0.0929	0.07625	0	
1	ON02GD9041	07/17/18	0.134	0.07625	0	
1	ON02GD9041	07/31/18	0.0559	0.07625	100	
1	ON02GD9041	08/14/18	0.0461	0.07625	100	
1	ON02GD9041	08/28/18	0.0745	0.07625	100	
1	ON02GD9041	09/11/18	0.0581	0.07625	100	
1	ON02GD9041	09/25/18	0.0518	0.07625	100	
1	ON02GD9041	10/09/18	0.0563	0.07625	100	
1	ON02GD9041	10/23/18	0.0253	0.07625	100	

4. Calculate the region score by averaging all site scores in each region.

Region	Site	Site Scores	Region Scores
1	ON02GD9041	72	64
1	ON02GD9048	61	
1	ON02GD9056	44	
1	ON02GD9057	83	
1	ON02GD9058	74	
1	ON02GD9059	61	
1	ON02GD9061	56	
2	ON02GE0007	29	34
2	ON02GE1000	19	
2	ON02GE1005	75	
2	ON02GE1006	33	
2	ON02GE1007	14	
2	ON02GE9055	33	
2	ON02GE9056	39	
2	ON02GG1000	30	

Figure 4. Example scoring method.

Multiple thresholds provide a more nuanced understanding of conditions and can be scored in a number of ways. One common approach is to assign a score based on multiple thresholds, as in Table 1. This score is then converted to the report card scale described below. Another common approach is to use linear equations to convert a sampling value to a report card score, as in Table 2.

Table 1. Example of the multiple-threshold approach using fish consumption advisories (Servings per Month) and their corresponding report card score. Note that these scores are from a different project and differ slightly from the scores used in this project.

Servings per Month	Report Card Score
0	0
<1	10
1	20
2	30
4	40
8	50
12	60
16	70
24	80
32	90
unrestricted	100

Table 2. Multiple thresholds scoring example using a fish index biotic of integrity (FBI) from Ontario. Note that this example was not used in this project, it simply illustrates the multiple equations approach to scoring. The value *"x"* in these equations is the FBI score.

FBI	Report Card Score	Equation
0	100	y = -4.6948x + 100
4.26	80	y = -26.667x + 193.6
5.01	60	y = -26.667x + 193.6
5.76	40	y = -26.667x + 193.6
6.51	20	y = -26.667x + 193.6
10	0	y = -5.7307x + 57.307

The most detailed level of data that was available was scored against the threshold whether that was at a sample level, station level, county level, or other scale. Once each measure was compared to a pass/fail or multiple-threshold scale and assigned a score, it was averaged.

For indicators measured at sample stations, each sample was averaged to the station level. The number of samples at a station may also vary, with some stations only sampled once while others were sampled many times.

Each station score within a watershed was averaged together to calculate a watershed score for that indicator. For most indicators the scoring scale follows a 20-point scale of 0−100%, (Table 3). However, some indicators were scored on the more strict 10-point scale because they were particularly important to the watershed groups or affected human health. The Beach Access and Sewer Overflows were assessed on a 10-point scale. Scores less than 60 were considered “Very poor”, 60-70 as “Poor”, 70-80 as “Moderate”, 80-90 as “Good”, and greater than 90 as “Very good”. This score was converted to the 20-point scale to make scores comparable across indicators.

Table 3. Report card scores and narrative.

Score (%)	Description
80–100	Very good
60–80	Good
40–60	Moderate
20–40	Poor
0–20	Very poor

Some indicators were scored at the county or census block level. In these cases, the proportion of the county or census block area that fell within a watershed was used to weight that indicator’s score at the watershed scale.

Indicators from the same category were averaged together to calculate a category score for the watershed. Category scores were averaged to calculate overall watershed scores. Synthesizing information at the watershed scale can be used to assess small improvements or declines in social, economic, and ecosystem health (Figure 5).

Figure 5. Report card scoring descriptions**.** A “very good” score (80–100%) shows that all indicators met objectives, often leading to preferred conditions. A “good” score (60–79%) shows that most indicators meet objectives, often leading to acceptable conditions. A “moderate” score (40–59%) shows that some indicators meet objectives and others do not. This leads to sufficient conditions. A “poor” score (20–39%) shows that few indicators meet objectives, often leading to degraded conditions. A “very poor” score (0–19%) shows that very few or no indicators meet objectives, leading to unacceptable conditions.

To calculate overall regional scores, watershed scores were weighted by either their population size or area (Table 4). Watershed-level population sizes were calculated from U.S. Census data from 2021 at the census block level as the sum of the census block population multiplied by its proportional area within a watershed. Watershed areas were calculated using ArcGIS.

Indicator scores that were area-weighted were Bird Diversity, Benthic Community, Fish Populations, Forests, Protected Lands, Tree Cover, Wetlands, Farmland, Impervious Surfaces, Dissolved Oxygen, Nitrogen, Phosphorus, Turbidity, and Water Temperature. Indicators that were population-weighted were Cost of Flooding, Income Equality, Household Income, Local Ownership, River Economy, Trade, Air Quality Index, Bacteria, Environmental Justice, Fish Consumption, Heat Vulnerability Index, Affordable Housing, Flooding, Sewer Overflows, Beach Closures, Fishing, Parks, Walkability, and Watercraft Access.

Table 4. Weighting schemes used to calculate overall scores for southeast Michigan.

Watershed	Population Size	Population Weight	Area (km^2)	Area Weight
Clinton	1,289,119	0.33	1979	0.22
Detroit	475,372	0.12	515	0.06
Huron	627,412	0.16	2379	0.27
River Raisin	180,889	0.05	2753	0.31
Rouge	1,352,088	0.34	1211	0.14

Economic Indicators

Cost of Flooding

was developed by the Federal Emergency Management Agency (FEMA) to assess a community's risk from flooding on an annual basis. Data was downloaded at the county level and integrates a community's population size, property values, and agricultural value (FEMA, 2023). This indicator is a useful economic measure of the likely annual costs of flooding.

Data source: https://hazards.fema.gov/nri/riverine-flooding

Calculation method: Scores at the county-level were calculated by comparing counties in southeast Michigan to percentiles (0, 25th, 50th, 75th, and 100th) of FEMA index scores for all of Michigan. The FEMA index scores were converted to a 0-100 scale using threshold-specific equations (Table 5).

Table 5. Equations used to convert FEMA Index scores to a 0-100 scale based on percentiles (0, 25th, 50th, 75th, and 100th) for all Michigan counties.

FEMA Index Threshold	Report Card Score	Equation
< 2.68	100–75	y = -9.3284x + 100
< 6.04	74–50	y = -7.4405x + 94.94
< 7.91	49–25	y = -13.369x + 130.75
< 43.85	24–0	y = -0.6956x + 30.502

County-level scores were population weighted and summed to calculate the watershed score. Watershed scores were weighted by their population size to calculate an overall score for southeast Michigan.

Household Income

uses the county-level median household income, which helps illuminate the financial resources and economic well-being of the typical household in a community.

Data source: Data was downloaded at the county-level from the US Census Bureau (US Census Bureau) for 2020.

Calculation method: County-level median household incomes were scaled from 0 to 100 based on percentiles (0, 25th, 50th, 75th, 100th) for all counties in Michigan using threshold-specific equations, with higher household incomes scoring better (Table 6).

Table 6. Equations used to convert county-level median household incomes to a 0-100 scale.

Median Household Income Threshold	Report Card Score	Equation
> 57,414	100–75	y = 0.0009x + 21.562
> 51,470	74–50	y = 0.0042x - 166.48
> 47,189	49–25	y = 0.0058x - 250.57
≤ 47,189	24–0	y = 0.0028x - 108.56

Population-weighted county scores were summed to calculate the watershed score. Watershed scores were weighted by their population size to calculate an overall score for southeast Michigan.

Income Equality

is based on the Gini coefficient, which measures income inequality as the difference between the observed cumulative income distribution in an area and a perfectly equal income distribution (Gini index description). The Gini coefficient ranges from 0 to 1, with larger values indicating greater income inequality. As a general rule, Gini scores < 0.2 represent perfect income equality while scores > 0.5 indicate severe income gaps, thus a score of 0.4 can serve as a warning level of income inequality (Teng et al. 2011).

Data source: Data was downloaded at the county-level from the US Census Bureau (US Census Bureau) for 2020.

Calculation method: County-level Gini coefficient scores were converted to a 0–100 scale so that a Gini coefficient of < 0.2 was scored as 100%, 0.2–0.3 was scored as 99%–80%, 0.3–0.4 was scored as 79%–40% range, and >0.4 ranged from 39%–0% (Table 7).

Table 7. Equations used to convert Gini coefficient scores to report card score (0-100).

Gini Coefficient Threshold	Report Card Score	Equation
< 0.2	100	
0.2–0.3	99–80	y = -200x + 140
>0.3–0.4	79–40	y = -400x + 200
>0.4	39–0	y = -400x + 200

County-level scores were population-weighted and summed to calculate the watershed score. Watershed scores were weighted by their population size to calculate an overall score for southeast Michigan.

Local Ownership

assesses the percentage of jobs at the county level that are from locally owned private businesses or locally controlled institutions (public or nonprofit) by using businesses with fewer than 500 employees as a proxy. This indicator is significant because economies more grounded in local ownership have higher job growth rates and are more resilient to economic crises.

Data source: Data at the county level from 2020 were from YourEconomy (https://youreconomy.org/)

Calculation method: This indicator was scaled from 0 to 100 using the equation, y = 200x - 100, with counties where if less than 50% of jobs were local the score was a 0. Population-weighted county scores were summed to calculate the watershed score. Watershed scores were weighted by their population size to calculate an overall score for southeast Michigan.

River Economy

considers two metrics to quantify changes in the contribution of river-related businesses to local economies. The indicator assessed percent change from 2019 to 2020 in total income generated from river-related businesses and the percent change in the total income per river job generated from river-related businesses. Total income includes the sum of wages, income, and taxes. River-related businesses were selected by stakeholders and included businesses from farming, utilities, construction, manufacturing, retail, transportation, real estate, service industry, tourism, and government sectors. This indicator helps inform whether river-related businesses are growing or declining in the region.

Data source: https://implan.com/

Calculation method: The percent changes in the total income and total income per job were scored using the equation, y = 10x + 50. With this scoring scheme, an increase of 5% was scored a 100 and a decrease of 5% was scored a 0. The scores for proportion of jobs and total were averaged to calculate a watershed score. Watershed scores were population-weighted to calculate an overall score for southeast Michigan.

Trade

assesses the net of exports and imports of an economy at the county level. A large surplus indicates very little "leakage" from the local economy and suggests a high amount of self-reliance and diversification for that county.

Data source: Data from 2020 (https://implan.com/)

Calculation method: The per capita trade balance at the county-level was converted to a 0-100 scale using the equation, y = 0.0017x + 50. Under this scoring scheme, a trade balance of $30,000 per capita was scored a 100 and a balance of -$30,000 per capita was scored a 0. County scores were population-weighted and summed to calculate a watershed score. Watershed scores were population-weighted to calculate an overall score for southeast Michigan.

Ecosystem Indicators

Benthic Community

assesses the community of small aquatic animals that live on the bottom of streams and rivers. Because some species are more sensitive to poor environmental conditions than others, the presence and relative abundance of different benthic macroinvertebrates provides an overall picture of a river's ecological condition.

Data source: All five watershed groups provided benthic macroinvertebrate data from their sampling programs for the most recent five years of data they had available, which ranged from 2016–2022.

Calculation method: Sampling sites were scored within a watershed according to the method used by the watershed group and then converted those scores to a standard scale (0–100) using threshold-specific equations (Table 8 and Table 9). Site-level scores were averaged annually at the watershed scale and the overall average across years was used to calculate the watershed score. Area-weighted watershed scores were summed to calculate an overall region score.

Table 8. Equations used to convert the original macroinvertebrate score to the report card scale for the Detroit, Huron, and River Raisin watersheds. Original scores were calculated using the MiCorp Volunteer Stream Monitoring Program.

MiCorp Score	MiCorp Descriptor	Report Card Score	Equation
0–3.50	Excellent	80–100	y = -4.444x + 100
3.51–4.50	Very Good		
4.51–5.50	Good	60–79	y = -9.5477x + 102.06
5.51–6.50	Fair	30–59	y = -4.0404x + 65.303
6.51–7.50	Fairly Poor		
7.51–8.50	Poor	20–29	y = -14.141x + 140.2
8.51–10.00	Very Poor	0–19	y = -12.752x + 127.52

Table 9. Original scoring scale and narrative description and corresponding report card score range for the Clinton and Rouge watersheds. Original scores were calculated using the Stream Quality Index method and converted to the report card scale using the rescale function in Program R (R Core Development Team).

Original Score	Descriptor	Report Card Score
>48	Excellent	80–100

34–48	Good	60–79
19–33	Fair	40–59
<19	Poor	0–39

Bird Diversity

assesses the number of species and their relative abundance. This indicator assessed bird diversity using Simpson's Diversity Index. Generally, a higher diversity of birds is an indicator of a healthy ecosystem. Birds play important roles in ecosystems, respond quickly to environmental disturbance, and generally have more data available compared to other taxonomic groups. Thus, birds are useful indicators for assessing ecological conditions and overall ecosystem health.

Data source: Audubon Christmas Bird Count for 2020 (https://www.audubon.org/conservation/science/christmas-bird-count)

Calculation method: Christmas bird survey areas that at least partially occurred within a watershed were combined to calculate Simpson's Diversity Index for that watershed. Simpson's Index is calculated as

$$D = 1 - \left(\frac{\sum \quad n_i(n_i-1)}{N(N-1)}\right)$$, where

n_i = Number of individuals for species i

N = Total number of individuals

This value was multiplied by 100 to calculate a watershed's score. Watershed scores were weighted by their area to calculate the overall score for southeast Michigan.

Fish Populations

assesses the condition of river and stream fish communities. Fish play important roles in these ecosystems, are diverse, relatively long-lived, and can respond quickly to changes in environmental conditions. Combined with the fact that species vary in their tolerance to environmental disturbances, these characteristics mean that the presence and relative abundance of different species can help us understand the overall condition of a river or stream.

Data source: Michigan Department of Natural Resources and Friends of the Rouge from 2017–2021 for the Rouge River.

Calculation method: Stream sites were scored using a subset of Michigan's P51 scoring metrics (Michigan Biological Assessments): % tolerant species, % simple lithophilic species, % omnivorous species, % insectivorous species, and % piscivorous species. The the full set of 10 metrics was unable to be used because the thresholds for some metrics require information about stream widths, which were missing for the majority of sites. Thresholds are ecoregion-specific and overall scores were converted to the report card scale using threshold-specific equations (Table 10). If sites were sampled multiple times, the average score was used and those scores were averaged across a watershed to calculate an overall watershed score. The area-weighted watershed score was used to calculate the overall region score. R code for these calculations was modified from code generously provided by Olivia Williams.

Using the Simpson's Diversity Index was considered to score this indicator, but ultimately the P51 method was chosen because it is widely used and understood within Michigan and also provides a more detailed assessment of ecological condition than Simpson's Diversity Index.

Table 10. Original narrative and scoring thresholds from Michigan's P51 and the equations used to convert those scores to the report card scale. Note that we could only include 5 of the 10 metrics used in the Michigan P51, so our scores range from -5 to 5 (Reduced P51 Score) compared to -10 to 10 normally used (Full P51 Score).

P51 Narrative	Full P51 Score	Reduced P51 Score	Report Card Score	Equation
Excellent	10 to 5	5 to 2.5	80–100	y = 8x + 60
Acceptable	5 to -5	2.5 to -2.5	79–20	y = 12x + 50
Poor	-5 to -10	-2.5 to -5	19-0	y = 8x + 40

Forests

measures the percent change of forested land. Because of the numerous social, economic, and environmental benefits forests provide, protecting current forests and reforestation are key to improving watershed sustainability. This indicator assessed the amount of forest area change that occurred from 2016 to 2019, which was the most recent data available.

Data source: MRLC NLCD EVA Tool (https://www.mrlc.gov/eva/)

Calculation method: The percent difference in forest area between 2016 and 2019 was calculated. Percent change was converted to the report card scale using the equation, y = 20x + 50, with a loss of 2.5% scored a 0 and a gain of 2.5% scored a 100 (Table 11). Scores were capped at 0 or 100. Watershed scores were area-weighted to calculate an overall region score.

Table 11. Scoring thresholds used for the forests indicator. The equation to convert % change to a report card score was y = 20x + 50.

% Forest Change	Score	Letter Grade
-2.5 to -1.5	0–20	F
-1.5 to -0.5	20–40	D
-0.5 to 0.5	40–60	C
0.5 to 1.5	60–80	B
1.5 to 2.5	80–100	A

Protected Lands

are essential to reversing biodiversity loss. Numerous conservation and management organizations, including the federal government (America the Beautiful), have a goal to protect and manage 30% of lands and waters by 2030. This indicator assesses how close southeast Michigan watersheds are to the 30% goal for protected land.

Data sources:
PAD-US3.0 https://www.sciencebase.gov/catalog/item/62226321d34ee0c6b38b6be3

EGLE Conservation Easement Database https://gis-michigan.opendata.arcgis.com/datasets/egle::egle-conservation-easements/explore

National Conservation Easement Database https://www.conservationeasement.us/

Calculation method: The total protected area from PAD-US 3.0 for all GAP statuses, was used, which includes everything from permanently protected natural lands to conservation easements on working lands. Data was supplemented with conservation easements from the EGLE conservation easement database and the National Conservation Easement Database.

The total area of protected land was divided by the watershed area to calculate the percentage of protected land. The percentage of protected land was used as the watershed score, which was area-weighted to calculate an overall region score.

Tree Cover

is vital to protecting biodiversity and providing essential ecosystem services that support healthy watersheds. This indicator used thresholds from NOAA (NOAA Guidelines) for the amount of forested area that is needed to protect water quality.

Data source: https://www.mrlc.gov/data/nlcd-2016-usfs-tree-canopy-cover-conus-0

Calculation method: The percentage of tree cover area, also called canopy cover, was used for determining the area of a watershed that was forested. Data were analyzed at the census block scale. The area of tree cover in a census block was converted to a 0–100 scale using the equation, $y = x + 20$. Blocks with tree cover that were less than 20% were scored as 0, while those with 80% or more tree cover were scored a 100. The census block score was area-weighted to calculate a watershed score. Watershed scores were area-weighted to calculate an overall regional score.

Wetlands

measures the percent change in wetland area, which is essential for healthy freshwater ecosystems. Unfortunately, a huge number of wetlands have been lost since European settlement and these essential ecosystems continue to decline in Michigan, despite efforts to restore and create new ones (MI wetlands). Protecting remaining wetlands is critical for watershed sustainability. This indicator assesses the percent change in wetland area from 2016–2019.

Data source: (MRLC NLCD EVA Tool) https://www.mrlc.gov/eva/

Calculation method: The percent change in wetland area between 2016 and 2019 was calculated. Percent change was converted to the report card scale using the equation, $y = 20x + 50$, with a loss of 2.5% scored a 0 and a gain of 2.5% scored a 100 (Table 12). Scores were capped at 0 or 100. Watershed scores were area-weighted to calculate an overall region score.

Table 12. Scoring thresholds used for the wetlands indicator. The equation to convert % change to a report card score was, $y = 20x + 50$.

% Wetland Change	Score	Letter Grade
-2.5 to -1.5	0–20	F
-1.5 to -0.5	20–40	D
-0.5 to 0.5	40–60	C
0.5 to 1.5	60–80	B
1.5 to 2.5	80–100	A

Human Health Indicators

Air Quality Index

measures overall air quality. Degradation in air quality has been linked to numerous diseases in humans and can damage buildings, crops, and ecosystems. The U.S. EPA monitors six common air pollutants that are of special concern and has developed standards for these pollutants to protect human and environmental health (https://www.epa.gov/criteria-air-pollutants). This indicator includes three of those pollutants: two different size categories of particulate matter and ozone. However, not all of these pollutants were available for all of the watersheds (Table 13).

Table 13. The air quality pollutants that were available for each watershed. We scored particulate matter with a diameter less than 2.5 microns (PM 2.5) and less than 10 microns (PM 10) and ozone (O_3) . ✓ = data was available, X = data was not available.

Region	PM 2.5	PM 10	O_3
Clinton	✓	X	✓
Detroit	✓	✓	✓
Huron	✓	X	✓
Raisin	✓	✓	✓
Rouge	✓	✓	X

Data source: Daily data was downloaded from the US EPA (US EPA Air Quality Data) for 2021.

Calculation method: Scores were calculated individually for the air quality metrics, with thresholds based on the EPA thresholds for the Air Quality Index (AQI; Table 14). If multiple air quality stations were located within the same watershed, they were scored separately and averaged at the watershed-scale. Watershed scores were population-weighted to calculate an overall region score.

Table 14. Air Quality Index (AQI) thresholds and narrative from the US EPA and their corresponding Report Card Scores and the equations used to convert scores to the report card scale.

AQI Score	AQI Narrative	Report Card Score	Equation

0–50	Good	100–60	y = -0.8x + 100
50–100	Moderate	59–40	y = -0.4x + 80
100–150	Unhealthy for Sensitive Groups	40–0	y = -0.8x + 120
> 150	Unhealthy	0	

Bacteria

in freshwaters can pose a human health risk if present at high levels, potentially causing a variety of diseases. Bacteria can enter water bodies from point and nonpoint sources and are particularly problematic following storms. This indicator assesses *Escherichia coli (E. coli*) in the water during the summer season (May 1st–September 30th), when recreation is highest, against the Michigan Department of Environment, Great Lakes, and Energy's threshold.

Data source: Data from 2015 to 2022 were downloaded from the National Water Quality Monitoring Council's data portal (https://www.waterqualitydata.us/).

Calculation method: The geometric mean was calculated from each sampling station using the most recent sampling year available, which ranged from 2019 to 2021 depending on the station. Stations were scored pass/fail based on the threshold of 130 per 100ml. Station scores were averaged to calculate the watershed score. Watershed scores were population-weighted to calculate the overall region score.

Environmental Justice

is an index that was developed by the Centers for Disease Control and Prevention to assess the impacts of environmental inequality on human health. This index considers 36 environmental, social, and health factors at the census block level for the entire United States.

Data source: https://www.atsdr.cdc.gov/placeandhealth/eji/index.html#:~:text=The%20 Environmental%20Justice%20 Index%20 uses,health%20for%20every%20census%20tract for 2022.

Calculation method: Census block environmental justice index (EJI) scores were population-weighted based on the proportion of the census block that occurred within a watershed to calculate the watershed score. Watershed scores were population-weighted to calculate an overall region score. Note that EJI scores were inversely scaled to convert it to the report card scale because it ranges from 0 to 1, with 1 indicating a higher environmental risk.

Fish Consumption

advisories are the result of a legacy of pollution that has led to the widespread presence of long-lived chemicals in Michigan's environment. Some of these chemicals make their way into fish and can harm people when they eat contaminated fish. The Michigan Department of Health and Human Services has developed fish consumption guidelines to limit people's exposure to these hazardous chemicals. This indicator assesses how fish contamination affects people's ability to consume fish safely in southeast Michigan.

Data source: Eat Safe Fish Guide 2022 for Southwest and Southeast Michigan from the Michigan Department of Health and Human Services.

Calculation method: Fish species were scored based on the recommended number servings (Table 15). The average scores for all species and sampling areas within a watershed were averaged to calculate watershed scores. Watershed scores were population-weighted to calculate an overall score for the region.

Table 15. Scoring based on the number of servings as recommended in the Michigan Department of Health and Human Service's Eat Safe Fish Guide for 2022.

Servings Per Month Thresholds	Report Card Score
Do Not Eat	0
Limited	10
6 per year	20
1 per month	30
2 per month	40
4 per month	50
8 per month	70
12 per month	85
16 per month	100

Heat Vulnerability

is an index developed by NASA and Groundwork USA (Groundwork USA) to assess a community's potential vulnerability to climate change. Data is available at the census block level and integrates information about the amount of tree coverage (tree canopy), impervious surfaces, land surface temperature, and percentage of households in poverty.

Data source: Tree canopy and impervious surfaces were calculated from the National Land Cover Database 2019 data, land surface temperature was calculated from Google Earth Engine, and percentage of households in poverty was calculated from the US Census Bureau's 2019 data.

Calculation method: The heat vulnerability index was calculated using the methods described by Groundwork USA and converted to the report card scale for each census block (Table 16). The population weight of a census block was calculated by multiplying the census block population by the proportion of the census block occurring within a watershed. The population-weighted census block scores were summed to calculate the watershed score. Watershed scores were population-weighted to calculate the overall region score for southeast Michigan.

Table 16. Heat Vulnerability Index scoring.

Heat Vulnerability Index	Report Card Score	Report Card Grade
4 to 0	0–19	F
0 to -1	20–39	D
-1 to -2	40–59	C
-2 to -3	60–79	B
-3 to -4	80–100	A

Infrastructure Indicators

Affordable Housing

measures how much of a household's income is spent on housing. Generally, housing is considered affordable when households pay less than 30% of income on rent or mortgage costs.

Data source: US Census Bureau; American Community Survey, ACS 2021 (1-Year Estimate; ACS Survey Data)

Calculation method: Data was scored at the county level and based on the percentage of households that spend less than 30% of their income on rent or mortgage costs. County scores were population-weighted to calculate watershed scores. Watershed scores were population-weighted to calculate an overall score for southeast Michigan. In the future, a stricter scoring scale is recommended for this indicator.

Farmland

measures the change in agricultural land area from 2016–2019 in southeast Michigan. Farmland loss is widespread in the US (American Farmland Trust) and threatens our ability to sustain ourselves and can be damaging to a community's economy and culture.

Data source: MRLC NLCD EVA Tool (https://www.mrlc.gov/eva/)

Calculation method: The percent change in land classified as agricultural from 2016 to 2019 was calculated for each watershed. Percent change was converted to the report card scale using the equation, y = 20x + 50, with a loss of 2.5% scored a 0 and a gain of 2.5% scored a 100. Scores were capped at 0 or 100. Watershed scores were area-weighted to calculate an overall region score.

Flooding

assesses how the number of property-damaging floods has changed in southeast Michigan in the most recent five years of data (2017–2021) compared to the previous 10 years (2007–2016). Human changes to the landscape in southeast Michigan, such as removing forests and wetlands for development and agriculture and burying streams beneath pavement (i.e., ghost streams), means that more water runs off the landscape into rivers and streams during rains and when snow melts. Combined with potential changes in rainfall patterns in recent years, these landscape changes increase the amount of flooding in this region.

Data source: National Oceanic and Atmospheric Administration's storm events database (https://www.ncdc.noaa.gov/stormevents/)

Calculation method: This indicator was scored at the watershed scale using the average number of floods reported in the NOAA storm events database for the most recent five years of available data, 2017–2021. The threshold used for scoring was the average number of floods from 2007–2016 (average = 0.72). If the number of floods was less than the average, then the score was calculated as y = -69.4444x + 100, where x is the average number of recent floods in a watershed. If the number of floods was greater than the average, then a score was calculated as y = -64.103x + 96.154. Using this scoring method, a watershed would score a 50% if the number of floods in the most recent five years was equal to the average from 2007–2016.

Using river flood levels from USGS gages in the region was explored, but found that the coverage was too limited and/or established flood height information was lacking for many gages.

Impervious Surfaces

are hard surfaces (*e.g.*, paved roads, parking lots, and buildings) that prevent water from soaking into the ground. These surfaces increase the amount of water running off the landscape which then picks up pollutants along the way. These surfaces also affect local temperatures and increase heat in urban areas. This indicator assesses the amount of impervious surfaces in a watershed using thresholds from the NOAA Office for Coastal Management (NOAA Guidelines).

Data source: NLCD 2019 (https://www.mrlc.gov/data?f%5B0%5D=category%3AUrban%20Imperviousness)

Calculation method: The percentage of impervious surface area in a watershed was calculated at the census block level. The area of impervious surfaces in a census block was converted to a 0–100 scale using two equations (Table 17). The census block score was area-weighted to calculate a watershed score. Watershed scores were area-weighted to calculate an overall regional score.

Table 17. Scoring thresholds and equations for the percentage of impervious surfaces.

Impervious Surface %	Score	Equation
20–5	0–59	y = -8x + 100
5–0	60–100	y = -4x + 80

Sewer Overflows

assesses the number of untreated wastewater events from combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs). These overflows are mostly associated with heavy rains that overwhelm the capacity of the wastewater management system, although some SSOs may result from things like pipe ruptures. This untreated waste poses a threat by potentially exposing people, animals, and plants to harmful bacteria, viruses, parasites, and toxins. Additionally, excess organic matter can harm wildlife by lowering dissolved oxygen levels and excess nutrients can contribute to eutrophication in river and coastal areas.

Data sources: The Michigan Department of Environment, Great Lakes, and Energy Combined Sewer Overflow (CSO), Sanitary Sewer Overflow (SSO), and Retention Treatment Basin (RTB) Discharge annual reports from 2019, 2020, and 2021.

Calculation method: Each permitted CSO or SSO site was scored as pass/fail for each year to get an average score for that site across the three years of data (2019, 2020, 2021). This scoring system is based on the goal of having no untreated wastewater discharges occur at a CSO or SSO site. Site scores for both CSOs and SSOs sites within a watershed were averaged to calculate a watershed score. The 10-point grading scale was used for this indicator because of the human health concern associated with the discharge of untreated waste (Table 18). Watershed scores were population-weighted to calculate a region score. Based on expert judgement from the Friends of the Rouge, the Rouge River watershed was assigned a 0% score because of the alarmingly high number of CSO overflows (470 in 3 years) in this watershed.

The volume of untreated wastewater was considered as a metric for this indicator, but it was not used because of permit-specific differences in allowable discharge amounts and unclear guidance for what is considered an “acceptable” amount for protecting human and environmental health. Releases from Retention Treatment Basins (RTBs) were not included because these receive at least partial treatment to acceptable levels for protecting human health.

Table 18. Scoring for sewer overflows indicator and equations used to adjust scoring from 10-point scale to the more typical Report Card Scale. The equation for an F was y = 0.3x, while all other grades used y = 0.5x + 50.

Adjusted Scale	Report Card Scale	Grade	Equation
0–60	0–20	F	y = 0.3x
60–70	20–40	D	y = 0.5x + 50
70–80	40–60	C	y = 0.5x + 50
80–90	60–80	B	y = 0.5x + 50
90–100	80–100	A	y = 0.5x + 50

Recreation Indicators

Beach Access

measures whether public beaches were closed or under an advisory for human health concerns from high bacteria levels and other pollutants in beach waters. Public beaches are recreationally important resources that support local economies and are places for people to enjoy southeast Michigan’s rivers and lakes. Thus, beach advisories and closures are harmful in a number of ways and can also contribute to a negative view of the overall condition of the environment in southeast Michigan.

Data source: Michigan Department of Environment, Great Lakes, and Energy’s BeachGuard program (https://www.egle.state.mi.us/beach/) for 2021.

Calculation method: This indicator was scored by the percentage of days a public beach was under an advisory or closed during the 2021 summer season (Memorial Day to Labor Day). If multiple beaches were present in a watershed, the average score of those beaches was used to calculate the watershed score. Watershed scores were population-weighted to calculate the region score.

Fishing

measures the number of fishing license holders in each watershed. Recreational fishing helps support local economies and encourages environmental stewardship by helping people connect with and value nature. While it does not necessarily mean people are staying within the watershed for fishing, it provides a general indicator of recreational fishing enthusiasm in these watersheds.

Data source: The Michigan Department of Natural Resources provided fishing license data at the zip code level from 2013–2021. We used the most recent available data (2021) for this analysis.

Calculation method: This indicator was scored by comparing the number of fishing licenses in a zip code tabulation area (ZCTA) to the 75th percentile for all of Michigan. A ZCTA was scored a 100% if it was equal to or above the 75th percentile. For ZCTAs below the 75th percentile, scores were calculated as

$$Score = \left(\frac{ZTCA_i}{MI\ threshold}\right) * 100, \text{ where}$$

$ZTCA_i$ = number of licenses in a given ZTCA

MI threshold = 75th percentile of all Michigan ZTCAs

The proportion of a ZTCA's area within a watershed was multiplied by its population to calculate a population weight. The population weight was multiplied by the ZCTA score and summed to calculate a watershed score. Watershed scores were population weighted to calculate an overall region score.

Parks

are often the best opportunity for city residents to interact with nature. Urban parks also promote community well-being by improving physical and mental health, providing numerous ecosystem services, and increasing social interactions. Because of the absence of detailed information about park amenities (e.g., facilities, viewsheds, etc.), this indicator uses metrics of park size as surrogates for park quality.

Data source: Trust for Public Land

Calculation method: This indicator was scored using the park acreage metrics of the Trust for Public Land's ParkScore methodology. Park acreage includes the median park size and the percentage of a city's area that was parkland. Watersheds were scored based on the 75th percentile of the park acreage metrics for southeast Michigan. Park metrics were scored a 100%

if they were equal to or greater than the 75th percentile. Park metrics below the 75th percentile were scored by

$$Score = \frac{\left(\left(\frac{UA_M}{Region\ threshold}\right)*100+\left(\frac{UA_P}{Region\ threshold}\right)*100\right)}{2}, \text{ where}$$

UA_M = Median Park Size (km) in a given Urban Area
UA_P = Proportion of Parkland in a given Urban Area
Region threshold = 75th percentile of all SE Michigan UAs for the respective acreage metric

Urban area scores were area-weighted to calculate a watershed score. Watershed scores were population-weighted to calculate an overall region score.

Walkability

to an urban park is an important measure of a community's access to green spaces and the benefits they provide. This indicator considers the ability of a person to have a 10-minute walk to the nearest public park. The travel time is calculated using the shortest walking route without a barrier (*e.g.*, highway, train track, etc.).

Data source: Trust for Public Land for ParkScore and U.S. Census Bureau for Urban Areas shapefile.

Calculation method: The overall percentage of the population that can walk to a park in 10 minutes from the Access metric of the Trust for Public Land's ParkScore methodology was used to score this indicator. This data is available at the level of the US census bureau's urban area designation. The proportion of an urban area within a watershed was multiplied by its population size to calculate a population weight. An urban area's walkability score was multiplied by its population weight and summed to calculate a watershed score. Watershed scores were population-weighted to calculate the overall region score. This population weight only includes urban area populations.

Watercraft Access

measures the number of large or small watercraft launches that are available in the major rivers in Southeast Michigan. Increasing access for recreation opportunities and getting more people out on the water is an important goal for the watershed groups in this region.

Data sources: Michigan Department of Natural Resources and stakeholder provided data

Calculation method: This metric was scored by determining whether or not a watercraft access point was available every 2 miles along a river's main stem. The main stem, as identified by the appropriate watershed group, was divided into two-mile segments. Segments with least one access point were scored a 100%, while those without an access point were scored a 0%. The average score for all segments along the main stem were used to score the watershed. Watershed scores were population-weighted to calculate an overall regional score.

Water Indicators

Dissolved Oxygen

measures the availability of oxygen for aquatic animals. From eutrophication to warmer temperatures, a number of threats can reduce oxygen availability and harm aquatic ecosystems. For dissolved oxygen, data from the productive summer months of May–September were used to determine whether dissolved oxygen levels in water were able to sustain life.

Data sources: National water quality monitoring council water quality portal (waterqualitydata.us), Huron River Watershed Council, and River Raisin Watershed Council. Data cover the years 2015–2022 to ensure adequate data for analysis.

Calculation method: Sampling events were scored pass/fail based on the EPA threshold of 5 mg/L. Samples above the threshold passed (100%), while samples below thresholds failed (0%). An average score was calculated for survey sites that were sampled multiple times. Site scores were averaged to calculate a watershed score. Watershed scores were area-weighted to calculate an overall region score.

Nitrogen

is an essential nutrient, but too much pollutes waters and degrades ecosystems. Excess nitrogen can alter food quality and community composition, lead to eutrophication, and may cause harmful algal blooms.

Data sources: Total nitrogen (TN) data from the National Water Quality Monitoring Council Water Quality Portal (waterqualitydata.us) and Nitrate-Nitrite (NN) data from the Huron River Watershed Council. Data from the years 2016–2022 were used to ensure adequate data for analysis.

Calculation method: Samples were scored as pass/fail using U.S. EPA ecoregion-specific thresholds for TN (regions 55 and 57 = 2.18 mg/L, region 56 = 1.15 mg/L) and NN (regions 55 and 57 = 1.5 mg/L, region 56 = 1.15 mg/L). The Huron River watershed and Detroit Tributaries sub-region were scored using NN, while all other watersheds were scored using TN. Samples above the threshold failed (0%) while samples below thresholds passed (100%). Stations sampled multiple times were averaged. Station scores within a watershed were averaged to score watersheds, which were area-weighted to calculate an overall region score.

Phosphorus

is an essential nutrient, but can also harm ecosystems at high concentrations.

Data sources: Total phosphorus (TP) data from the National Water Quality Monitoring Council Water Quality Portal (waterqualitydata.us), the Huron River Watershed Council, and from the River Raisin Watershed Council. Data from the years 2016–2022 were used to ensure adequate data for analysis.

Calculation method: Samples were scored as pass/fail using US EPA ecoregion-specific thresholds (regions 55 and 57 = 0.07625 mg/L, region 56 = 0.033 mg/L). Samples above the threshold failed (0%) while samples below thresholds passed (100%). Stations sampled multiple times were averaged. Station scores within a watershed were averaged to score watersheds, which were area-weighted to calculate an overall region score.

Turbidity

measures water clarity and is an important indicator of water quality. High turbidity levels can disrupt aquatic ecosystems, potentially indicate other pollutants (e.g., metals and bacteria), and can impact recreation and tourism.

Data sources: Turbidity data from the National Water Quality Monitoring Council Water Quality Portal (waterqualitydata.us) and River Raisin Watershed Council; Total Suspended Solids data from the Huron River Watershed Council. Data from the years 2016–2022 were used to ensure adequate data for analysis.

Calculation method: Samples were scored as pass/fail using EPA eco-region-specific thresholds (Regions 55 and 57 = 6.36 NTU, Region 56 = 14.5 NTU). The Huron River Watershed Council provided total suspended solids (TSS), which was scored using the Maumee Watershed Action Plan's 25 mg/L. The Huron River watershed was scored using TSS, all other watersheds were scored using turbidity. Samples above the threshold failed (0%) while samples below thresholds passed (100%). Stations sampled multiple times were averaged. Station scores within a watershed were averaged to score watersheds, which were area-weighted to calculate an overall region score.

Water Temperature

affects freshwater aquatic ecosystems in numerous ways. Warming temperatures can stress aquatic animals and also allows warm-water adapted species to outcompete species adapted to cooler temperatures. As temperatures continue to rise, even warm-water adapted species can become stressed and may ultimately have to move or die. Warming water can also increase oxygen demand while simultaneously reducing oxygen levels in water, further stressing aquatic animals.

Data sources: National Water Quality Monitoring Council Water Quality Portal (waterqualitydata.us) and River Raisin Watershed Council. Data from the years 2015–2022 were used to ensure adequate data for analysis.

Calculation method: Samples were scored using the Part 4 water quality standards from the Michigan Department of Environment, Great Lakes, and Energy. April through September temperatures in this analysis. Thresholds vary by month and were 12.2° Celsius for April, 18.3° Celsius for May, 20° Celsius for June through August, and 17.2° Celsius for September. Water temperatures below the threshold were scored a 100% and water temperatures above the threshold were scored a 0%. Stations sampled multiple times were averaged. Station scores within a watershed were averaged to score watersheds, which were area-weighted to calculate an overall region score.

Table 19. Years and water quality parameters that were used to score water indicators for each watershed. We combined up to 7 years of data due to limited data availability. TN = Total Nitrogen, NN = Nitrate + Nitrite, TSS = Total Suspended Solids, DO = Dissolved Oxygen

	Nitrogen		Phosphorus	Temperature	Turbidity		DO
Watershed	**TN**	**NN**	**TP**	**Temperature**	**Turbidity**	**TSS**	**DO**
Clinton	2016-2022	X	2016-2022	2016-2022	2016-2022	X	2017-2019
Detroit	2018-2022	X	2018-2022	2016-2022	2016-2018	2019	2015-2022
Detroit Tributaries	X	2017-2020	2017-2021	2017-2021	X	2017-2020	2017-2021
Huron	X	2017-2021	2016-2021	2015-2022	X	2016–2020	2016-2022
Raisin	2016-2022	X	2016-2022	2016-2022	2022	X	2015-2022
Rouge	2016-2022	X	2016-2022	2016-2022	2016-2022	X	X

Quality Assurance/Quality Control

After the report card data were analyzed, a second person checked all the data spreadsheets and R code. All numbers are compared to original spreadsheets to make sure there were not any errors transferring data. All calculations were also checked, to ensure equations have been entered correctly, and applied to the correct cells in the spreadsheet. The current dataset is small enough to check every indicator and every calculation. As datasets become larger and more complex for future report cards, it is recommended that a subset of data be checked. This can be done by comparing the current year's indicator score to the most recent previous indicator score. If the score is different by 33% (or a predetermined amount), those data should be flagged and checked for accuracy. Having proper quality assurance and quality control methods is vital to maintaining the integrity of the data and consistency in the information reported.

Watershed Scores

Economy

Region	Cost of Flooding	Income Equality	Household Income	Local Ownership	Trade	River Economy	Overall Economy
Clinton	11	21	88	80	56	50	51
Detroit	0	3	36	70	62	0	29
Huron	18	13	86	77	54	22	45
Raisin	34	26	78	84	22	68	52
Rouge	3	6	52	73	67	50	42
Overall	9	12	69	76	59	40	44

Ecosystem

Region	Wetlands	Forests	Tree Cover	Fish Populations	Birds Diversity	Benthic Community	Protected Lands	Overall Ecosystem
Clinton	55	35	44	28	93	45	29	47
Detroit	49	0	29	27	92	39	22	37

Huron	56	41	49	48	91	68	61	59
Raisin	52	39	32	51	90	55	12	47
Rouge	54	16	38	29	89	51	29	44
Overall	54	33	40	41	91	55	32	49

Human Health

Region	Fish Consumption	Bacteria	Heat Vulnerability	Air Quality	Environmental Justice	Overall Human Health
Clinton	34	0	28	72	60	39
Detroit	35	27	18	76	26	36
Huron	24	13	42	72	72	45
Raisin	34	17	40	75	54	44
Rouge	24	0	24	77	45	34
Overall	29	6	28	74	52	38

Infrastructure

Region	Impervious Surface	Farmland	Flooding	Sewer Overflows	Affordable Housing	Overall Infrastructure
Clinton	33	43	0	98	69	49
Detroit	7	0	45	0	60	22
Huron	51	38	32	94	67	56
Raisin	78	49	58	95	66	69
Rouge	5	0	0	0	63	14
Overall	47	35	13	52	65	42

Recreation

Region	Walkability	Parks	Beach Access	Watercraft Access	Fishing	Overall Recreation
Clinton	51	69	95	55	48	64
Detroit	66	48	64	79	74	66
Huron	70	65	96	77	62	74
Raisin	65	53	100	43	69	66
Rouge	63	72	NA	10	46	48
Overall	61	66	90	45	54	63

Water

Region	Nitrogen	Phosphorus	Dissolved Oxygen	Water Temperature	Turbidity	Overall Water
Clinton	25	64	95	50	35	54
Detroit	99	67	84	39	80	74
Huron	93	75	88	49	93	71
Raisin	12	53	85	49	21	44
Rouge	53	40	ID	42	8	36
Overall	47	60	88	48	45	58

Southeast Michigan

Watershed	Water	Ecosystem	Human Health	Infrastructure	Recreation	Economy	Overall Score
Clinton	54	47	39	49	64	51	51
Detroit	74	37	36	22	66	29	44

Huron	71	59	45	56	74	45	58
Raisin	44	47	44	69	66	52	54
Rouge	36	44	34	14	48	42	36
Overall	**58**	**49**	**38**	**42**	**63**	**44**	**49**

Data Availability

Watershed report cards are driven by scientific data and carefully selected thresholds so that the resulting scores can inform management decision-making. Consistent and rigorous data collection and availability is essential to creating useful and informative report cards. While data availability is almost always less than people expect or hope for, we were surprised at the limited amount of data for many indicators used or considered for this project.

Data availability issues were particularly problematic for indicators of ecosystem condition and water quality. We found that data was limited geographically, in quantity (e.g., few samples per year), or both throughout southeast Michigan. To overcome these limitations, we combined multiple years of data for several indicators (e.g., Table 19).

The data being collected by the watershed groups were invaluable for this project. Supporting these groups in their data collection efforts should be a priority. We would also encourage watershed groups, if they are not already, to participate in broader community science partnerships to ensure the data they are collecting is standardized and widely available.

Additional Indicators

The following indicators were explored, but ultimately not used in this report card.

Economic

Job Gains - The project team created and scored an indicator for job gains. The data source was the American Community Survey, 2019 and 2020. The indicator expressed jobs gained or lost per 1,000 residents in a county. Counties in Michigan vary from -14.74 (Alpena County) to 16.83 (Montmorency County). Higher, positive numbers indicate a growing economy; lower, negative numbers indicate a weakening economy. This indicator was not used in the report card because we could not determine an appropriate threshold for the region.

Tourism - The project team created and scored an indicator for tourism. The data source was MEDC, 2020 Statewide Spending. Two metric were evaluated, the number of tourism jobs per 1,000 residents in a county and the tourism wages paid per resident. Tourism jobs per 1,000 residents range from a 9 (Lenawee County) to 152 (Charlevoix County) in Michigan. Tourism wages per capita range from $295 (Lapeer County) to $5,914 (Charlevoix County) in Michigan. Tourism is an indicator of a successful river economy, but because tourism wages are often low, it's not necessarily a good indicator of economic strength. For this reason, the project team and watershed groups decided not to use this indicator.

Investment - During the stakeholder workshops, investment in Michigan was identified as an important value and indicator. However, after exploring the potential metrics for this, there was not sufficient data or thresholds to include it.

Ecosystem

Floristic Quality Index - Michigan FQI was available, but was based on data from 2014. Due to the age of the data, this indicator was not included.

Invasive Species - The Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS) was explored as a data source, but funding for aquatic invasive species tracking was cut in 2020, and not enough recent data was available for scoring. Also considered was the Michigan Invasive Species Program goal of managing and controlling 6,000 acres for terrestrial and aquatic invasive species, but the program has well exceeded this goal, and a map of the data was not available for watershed-level scoring.

Indicator Species - Red-side dace minnows, freshwater mussels, and mudpuppies were all considered as indicators, but not enough data was available to meaningfully score them.

Human Health

Drinking Water Advisories - Was identified during the workshops, but due to data availability and scoring issues, this indicator was not included in the analysis.

Infrastructure

Stormwater - The project team considered scoring this indicator by analyzing grants from EGLE as an indicator of overall stormwater infrastructure investment. Ultimately, this indicator was dropped because this approach did not adequately capture stormwater infrastructure investment or issues. The number of green infrastructure projects was also considered, but not scored, because of a lack of data and also a lack of clear goals.

Enclosed/Channelized Streams - We calculated the percentage of streams that were "channelized" by looking at the sinuosity of stream reaches in the NHD layer. Data from USGS NHD+ version 2 was used and we calculated % of stream miles with a sinuosity of <= 1.02, which generally indicates a straightened channel. This was compared to percentiles (0, 25, 50,75, 100) for all watersheds in the Great Lakes region. However, an ecologically relevant threshold could not be agreed upon and the indicator was not used.

Number of Superfund Sites - Superfund sites are a large problem in Southeast Michigan. The data source was EPA - Cleanups in My Community (CIMC) from 2022 available at https://www.epa.gov/cleanups/cleanups-my-community. Block Group population data was 2019 data from US Census. The population within 5km of each superfund site was determined. The population % near superfund sites was evaluated based on thresholds in Table 20. This indicator was ultimately not included because of lack of consensus on the thresholds and scoring.

Table 20. Thresholds used for a preliminary analysis and scoring.

Thresholds		
% pop nearby superfund site	**Score**	**Equation**
0	100	
5	60	y = -8x + 100
10	40	y = -4x + 80
25	0	y = -2.6667x + 6.667

Other indicators discussed but not analyzed or included were Waterway Designations and New Development/Redevelopment Projects.

Recreation

Trails - Trails was an important indicator to include for recreation. The data came from SEMCOG and included regional greenways and water trails, some sidewalks or roads, and some park trails (2019). Data sources were SEMCOG regional and trail explorer, Trust for Public Land trail layer in parks zip file, DNR's Iron Belle trail + Railtrail data. Scoring attempts were made by scoring trail length per person, trails per region, and looking at existing trails versus planned trails. At the time of this work, there were insufficient thresholds to score this indicator.

Fishing Access Sites - Fishing Access Sites (aka Recreational fishing sites) was one metric to access recreational fishing. Aside from the angler license indicator, location data for fishing sites that people could access for recreation was identified. Point data were available from Michigan DNR's "family fish" dataset (no date) and one additional DNR dataset (2022). Polygon data from SEMCOG provided parks that had fishing as a listed activity (updated in 2021). Scoring attempts were made by scoring sites per capita at the region level. Stakeholders proposed normalizing the sites within regions to look at regional averages. Also, an issue was brought up about contamination preventing access to sites that were not reflected in the available data, perhaps leading to an overrepresentation of available fishing spots. Additionally, affluence and ability to drive to spots was discussed briefly as a consideration. For scoring, attempts were made to use 1. (region - min)/(max-min) and 2. z-scores of using both a. land area for weighting, and 2. water body area for weighting. At the time of this work, the thresholds were insufficient and not robust enough to score this indicator.

Access to Green Space - Access to Green Space had the same number of votes of interest (8) as Parks so it was an important indicator to the stakeholders. However, data and thresholds for this indicator were sparse. Moreover, it was unclear, at least in retrospect, exactly what "access" meant. One of the proposed indicators to use was "Acres per capita/resident, Quality of green space" but no data or thresholds were reported. Additionally, spatial distribution of green space was proposed but was struck down likely due to complexity of analysis and/or unavailable data.

Boat registrations - Boat registrations was one proposed boating sub-indicator. Data was gathered via email communication with the Michigan Dept. of State (ListSales@michigan.gov). Watercraft registrations and titles per county were not useful since there was no distinction between recreational and commercial crafts. After sporadic communication with the data provider this indicator was ultimately dropped due to insufficient data.

Liveries - Liveries were identified as an important value and indicators in the regions, however there were insufficient data and thresholds and this was ultimately dropped.

Social and Cultural

Engagement: Watershed organizations were asked for engagement data such as number of volunteers, events, and environmental education programs. The types of engagement data collected differed widely between organizations. Additionally, engagement goals were not clearly defined by organizations. The lack of consistent goals and data led to this indicator being dropped.

Digital Engagement - Digital engagement was intended to assess how often residents of the watersheds were searching for information about the river, parks, nature-based recreation sites, etc. This indicator was scored using the top 5 search terms for each watershed according to Google Trends, but was dropped due to significant overlap with unrelated search terms interfering with the results, as well as the scores not feeling representative of the watersheds' populations.

Water

Chemical Contaminants - Stakeholders expressed concerns about PFAS in the water. Available data is sparse and relatively recent, and so PFAS was not included as an indicator. However, the concern of "forever chemicals" in the water supply was mentioned in the text.

Flow - There was not enough data throughout the watershed to score this indicator.

Socio-Environmental Report Card Benefits

Watershed report cards, much like school report cards, provide performance-driven numeric grades or letters that represent the relative ecological, social, and economic health of a geographic region or component of the ecosystem. They are an important tool for integrating diverse data types into simple scores that can be communicated to decision makers and the general public. In other words, large and often complex amounts of information can be made understandable to a broad audience.

Watershed report cards enhance research, monitoring, and management in several ways. For the research community, they can lead to new insights through integration schemes that reveal patterns not immediately apparent, help to design a conceptual framework to integrate scientific understanding and environmental values, and help to develop scaling approaches that allow for comparison in time. Within monitoring realms, report cards justify continued monitoring by providing timely and relevant feedback to managers and can have the added benefit of accelerating data analyses. For management and policy makers, they provide accountability by measuring the success of restoration efforts and identifying impaired regions or issues of socio-environmental concern. This catalyzes improvements in environmental, social, and economic health through the development of peer pressure among local communities. Report cards can also guide restoration efforts by creating a targeting scheme for resource allocation.

Report cards have become more common in recent years and are being produced by a variety of groups from small, community-based organizations to large partnerships. Although methods, presentation, and content vary, the underlying premise is the same: to build community awareness and raise the profile of issues around healthy and sustainable ecosystems, considering both the human and natural environment.

Some common elements of report cards include-

1. A map of the watershed or region
2. Indicator scores
3. A summary of key features (e.g., ecosystem types, recreation activities)
4. A “What You Can Do” Section

Citations

EcoCheck. 2011. Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

EcoCheck. 2013. Sampling and data analysis protocols for Mid-Atlantic non-tidal stream indicators. Wicks EC, Fries AS, Kelsey RH (eds). IAN Press, Cambridge, Maryland, USA.

Longstaff, B.J., T.J.B. Carruthers, W.C. Dennison, T.R. Lookingbill, J.M. Hawkey, J.E. Thomas, E.C. Wicks, and J. Woerner (eds). 2010. Integrating and applying science: A handbook for effective coastal ecosystem assessment. IAN Press, Cambridge, Maryland.

MDEQ. 1996. Staff report, Update of GLEAS Procedure 51 Metric Scoring and Interpretation. Michigan Department of Environmental Quality Surface Water Quality Division, June 1996. Revised October 30, 2018. https://www.michigan.gov/documents/deq/wrd-procedure-51-scoring-2018_637273_7.pdf

Pebesma, E. 2018. Simple features for R: standardized support for spatial vector data. The R Journal 10: 439-446.

R Core Team. 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Teng, F., J. He, X. Pan, and C. Zhang. 2011. Metric of carbon equity: carbon Gini Index based on historical cumulative emission per capita. Advances in Climate Change Research 2:134-140.