Development and Validation of a Benthic Index of Biotic Integrity (B-IBI) for Streams in Southeastern Minnesota.

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ABSTRACT

A benthic index of biotic integrity (B-IBI), comprehensive invertebrate index that represents a stream's biological health, was developed to detect the effects of human influence on stream systems. Invertebrate data from 43 stream sites in southeastern Minnesota were used to determine the ability of 22 characteristics (metrics) of invertebrate assemblages to assess the healthiness of streams in the region. Metrics (e.g., number of Plecoptera taxa, number of Clinger taxa) were tested to determine which could distinguish between impaired and unimpaired sites. The final B-IBI includes 10 metrics and 4 alternates. To validate the ability and sensitivity of the B-IBI, a score was determined for 12 new stream sites and compared to 4 physical habitat variables for each site. The B-IBI score was negatively correlated (r^2=0.49) with percent fine substrates and positively correlated (r^2= 0.57) with percent riffle habitat. The B-IBI developed is an effective tool in determining the health of stream ecosystems in southeastern Minnesota.

Introduction:

Biological monitoring is an essential process to assess the quality of waterways. The goal of biological monitoring is to pursue, evaluate and convey the conditions of an ecosystem and the effects that human activity has had on the system. Chemical testing to determine water quality is being phased out by the use of organism sampling in order to better understand the effects of pollutants on water quality. By examining the biota present in an ecosystem, not only can the biological impacts on a system be determined, but also the chemical and physical impacts as well [1, 2].

Multimetric indices are a vital tool used for biological monitoring. By evaluating several metrics, or biological attributes, the health of an ecosystem can be determined. Comparison of the characteristics of a specific water system to those of a high-quality system (one with minimal human disturbance) can ascertain and determine the negative aspects impacting that system [3]. Several variations of multimetric indices have been created since the early 1980s. Indices of Biotic Integrity are one form of multimetric index that focuses on fish, periphyton, or benthic communities. These IBIs are region-specific due to the variations in communities across a wide range of ecological habitats.

This paper reports the development and validation of a Benthic Index of Biotic Integrity (B-IBI) for streams in southeastern Minnesota. The invertebrate data used to create this index were collected solely from streams in this region, and therefore it is only applicable to streams in this area. Metrics used to create this index have proven effective in other indices created for other geographic regions; however, some metrics were not as effective for use in southeastern Minnesota as they have been elsewhere. The B-IBI developed was compared to several habitat variables, and was determined to be an excellent indicator of stream conditions in southeastern Minnesota.

Methods

A. Data Collection

Invertebrate data used to create the scoring system were collected from various streams throughout southeastern Minnesota over the past 4 years. Several people were involved in the invertebrate collection process, including Dr. Neal Mundahl of Winona State University, many of his student summer workers, and several citizen volunteers. Of the 43 total stream sites selected, 23 were classified as impaired sites, and 20 were classified as reference sites. Sites were grouped into these categories based on knowledge of their location and proximity to human disturbances, as well as preliminary analysis of their invertebrate assemblages. Impaired sites are those streams having been degraded by human actions in some way, and reference sites are those with minimal human disturbance and rich invertebrate assemblages.

B. Metric Selection

Table 1. Potential Benthic IBI Metrics and Their Predicted Response to Stream Impairment

	Metric	Predicted Response
Species Richness & Composition		
	Number of Taxa	Decrease
	Number of Ephemeroptera Taxa	Decrease
	Number of Plecoptera Taxa	Decrease
	Number of Trichoptera Taxa	Decrease
	Number of Long-Lived Taxa	Decrease
	Number of Diptera Taxa	Decrease
	Percent Ephemeroptera	Decrease
	Percent Plecoptera	Decrease
	Percent Trichoptera	Decrease
	Percent Long-Lived	Decrease
Tolerants and Intolerants		
	Number of Intolerant Taxa	Decrease
	Number of Tolerant Taxa	Increase
	Percent Intolerant	Decrease
	Percent Tolerant	Increase
	Percent Chironomids	Increase
Feeding and Other Habits		
	Number of Clinger Taxa	Decrease
	Number of Filterer Taxa	Variable
	Number of Predator Taxa	Decrease
	Percent Clinger	Decrease
	Percent Filterer	Variable
	Percent Predator	Decrease
Population Attributes		
	Percent Dominance	Increase

Table 2. Mean (+ SD) Values for Potential Benthic IBI Metrics at Reference (n= 20) and Impaired (n= 23) Sites, and Results of t-tests Between Reference and Impaired Sites

Metric	Reference Sites	Impaired Sites	t	P
Species Richness & Composition				
Number of Taxa	15.4 (11.7)	7.5 (5.4)	8.65	<0.001
Number of Ephemeroptera Taxa	3.7 (1.9)	1.3 (0.7)	6.68	<0.001
Number of Plecoptera Taxa	0.9 (0.4)	0.04 (0.04)	6.38	<0.001
Number of Trichoptera Taxa	3 (1.5)	1.6 (0.8)	4.35	<0.001
Number of Long Lived Taxa	1.4 (0.9)	0.3 (0.2)	4.54	<0.001
Number of Diptera Taxa	3.5 (2.6)	2.0 (1.3)	3.49	<0.001
Percent Ephemeroptera	30.0 (272.2)	21.5 (478.6)	1.45	0.077
Percent Plecoptera	4.5 (27.6)	0.2 (0.8)	3.61	<0.001
Percent Trichoptera	23.2 (280.1)	23.4 (856.5)	-0.02	0.493
Percent Long Lived	4.8 (33.5)	0.6 (1.5)	3.23	0.002
Tolerants and Intolerants				
Number of Intolerant Taxa	2.5 (2.5)	0.8 (0.9)	4.10	<0.001
Number of Tolerant Taxa	0.7 (0.8)	0.5 (0.5)	0.69	0.246
Percent Intolerant	14.0 (314.9)	9.1 (382.0)	0.87	0.194
Percent Tolerant	2.2 (23.7)	1.7 (26.3)	0.33	0.373
Percent Chironomids	7.0 (45.9)	13.7 (578.4)	-1.28	0.106
Feeding and Other Habits				
Number of Clinger Taxa	10.9 (5.3)	5.5 (4.1)	8.08	<0.001
Number of Filterer Taxa	3.2 (1.4)	1.8 (1.1)	3.89	<0.001
Number of Predator Taxa	2.6 (2.3)	0.9 (0.7)	4.22	<0.001
Percent Clinger	83.1 (136.7)	83.1 (711.2)	<0.01	0.500
Percent Filterer	30.2 (330.9)	29.8 (992.1)	0.05	0.479
Percent Predator	4.7 (22.1)	2.1 (6.8)	2.22	0.017
Population Attributes				
Percent Dominance	66.2 (105.4)	88.4 (77.8)	-7.54	<0.001

A variety of potential metrics for the B-IBI were determined by assessing previous versions of Benthic Indices (Table 1). The invertebrate attribute candidates cover a wide range of levels from individual to landscape and are selected to reveal important biological information [2]. Four broad metric categories were examined for metric selection: taxa richness and composition, tolerance, feeding and other habits, as well as population attributes; within those categories, only benthic species were examined (Table1). Taxa richness and composition focuses on the distinct number of taxa within a taxonomic group, as well as the proportions of individuals belonging to a specific taxonomic group. The tolerance of certain species is based on their ability to survive short and long- term stresses induced by habitat degradation as well as physiochemical pollutants. Feeding and other habits are based on the organism's mode of feeding and other common lifestyle methods such as clinging and filtering [4]. Population attributes focus on the combined effect of other individual metrics, such as percent dominance, which evaluates what proportion of the assemblage the top 3 most abundant taxa comprise. Using previous investigations, a predicted response to human influence was assigned to each metric [2, 4, 5, 6].

The metrics selected were based on their sensitivity to stream impairment. This was determined by comparing the values of each metric between reference and impaired sites. Means were calculated for each group and a t-test was used to determine if a significant difference existed. Metrics not showing a significant difference between the two categories were eliminated from further B-IBI development. Obviously, these metrics are not vulnerable to changes in stream habitat quality and therefore are of no further use to the index.

Many metrics are sensitive to the same change in conditions of a stream habitat. These metrics highly correlated with one anther do not contribute much new information to the B-IBI score [3]. Strong correlations occur most commonly in the species richness and composition category [5]. Pairwise correlations were calculated between metrics to determine which, if any, metrics could be eliminated.

C. Index Development and Scoring

Individual metrics not eliminated were scored following the procedure described by Lyons and Wang [7] and Mundahl and Simon [3]. A frequency distribution was created for each individual metric. The values were divided into equal thirds. The third of the values indicating stream habitats in the best condition were assigned a score of 10 (good), the middle third of values were assigned a score of 5 (fair), and the remaining third, representing the most degraded stream conditions, were assigned a score if 0 (poor). In metrics representing percentages, the 5th percentile of values representing pristine streams was eliminated first. Then, the thirds were determined and scored. This was to eliminate outlying values, as to not skew the scoring system. To obtain a final B-IBI score for a stream site, all the metric values for that stream were simply summed together. Qualitative ratings and descriptions of condition were created for five rating categories: excellent, good, fair, poor, and very poor.

Total B-IBI scores were calculated for each of the 20 reference and 23 impaired streams. A nonparametric median test then compared the reference and impaired stream scores to determine if the two categories differed significantly in scores.

Table 3. Alternate Metrics and Their Correlations with the Number of Taxa Metric

Alternate Metrics	**r**
Number of Ephemeroptera	0.828
Number of Clinger Taxa	0.955
Percent Dominance	-0.806
Number of Predator Taxa	0.763

D. Range of Metric Sensitivity and Metric to B-IBI Score Relationships

To deduce the framework and function of the Benthic IBI, total scores and individual metric scores were examined in two different ways. First, total B-IBI scores were plotted against individual metric scores for the 43 reference and impaired development sites. By examining each plot, the range of impairment within which that metric was most sensitive was determined. This range is where the most intense change occurs within the total B-IBI score across the metric values [3]. Secondly, the individual metrics and the B-IBI scores were compared using Spearman's rank correlation coefficient, to determine the significance of the relationship between the two values.

E. B-IBI Validation and Testing

To test the validity of the Benthic IBI, a new set of 12 sites from southeastern Minnesota was examined. These sites were from the Garvin Brook stream system and the Whitewater River stream system. These sites were previously tested for several physical habitat indicators: bare soil, percent embeddedness, percent fines, and percent riffle habitat. A B-IBI score for each of these sites and each physical habitat rating was plotted against the B-IBI scores for the 12 sites. Regression analysis and ANOVA testing were then performed to determine if any relationship existed between the B-IBI and the habitat indicators. A strong correlation indicates that the B-IBI is sensitive to the same stream impairments as the physical habitat indicators.

Results:

A. Metric Selection

Twenty-two potential metrics were tested for inclusion in the B-IBI (Table 1). Some metrics were eliminated because they either did not change in the manner predicted as human influence increased, or they did not discriminate between reference and impaired streams (Table 2). Percent Trichoptera, percent Ephemeroptera, percent clingers, percent filterers, and percent intolerant taxa, all failed to discriminate between reference and impaired sites, so they too were eliminated (Table 2). All metrics that could discriminate between reference and impaired sites are represented in Figure 1.

Four metrics (number of Ephemeroptera taxa, number of clinger taxa, number of predator taxa, and percent dominance) strongly correlated (r = 0.75) with the total number of taxa metric (Table 3), indicating redundancy in detecting impairment. However, these four metrics were not eliminated from the B-IBI. All four showed strong differences across reference and impaired stream habitats, and eliminating them would have eliminated all metrics from the population attributes category (Table 1, Figure 1). These four attributes have been categorized as alternate metrics that may be used in addition to the ten standard metrics (Table 3). The scoring system has been adjusted to use either the standard metrics or the four alternates in addition to the standards.

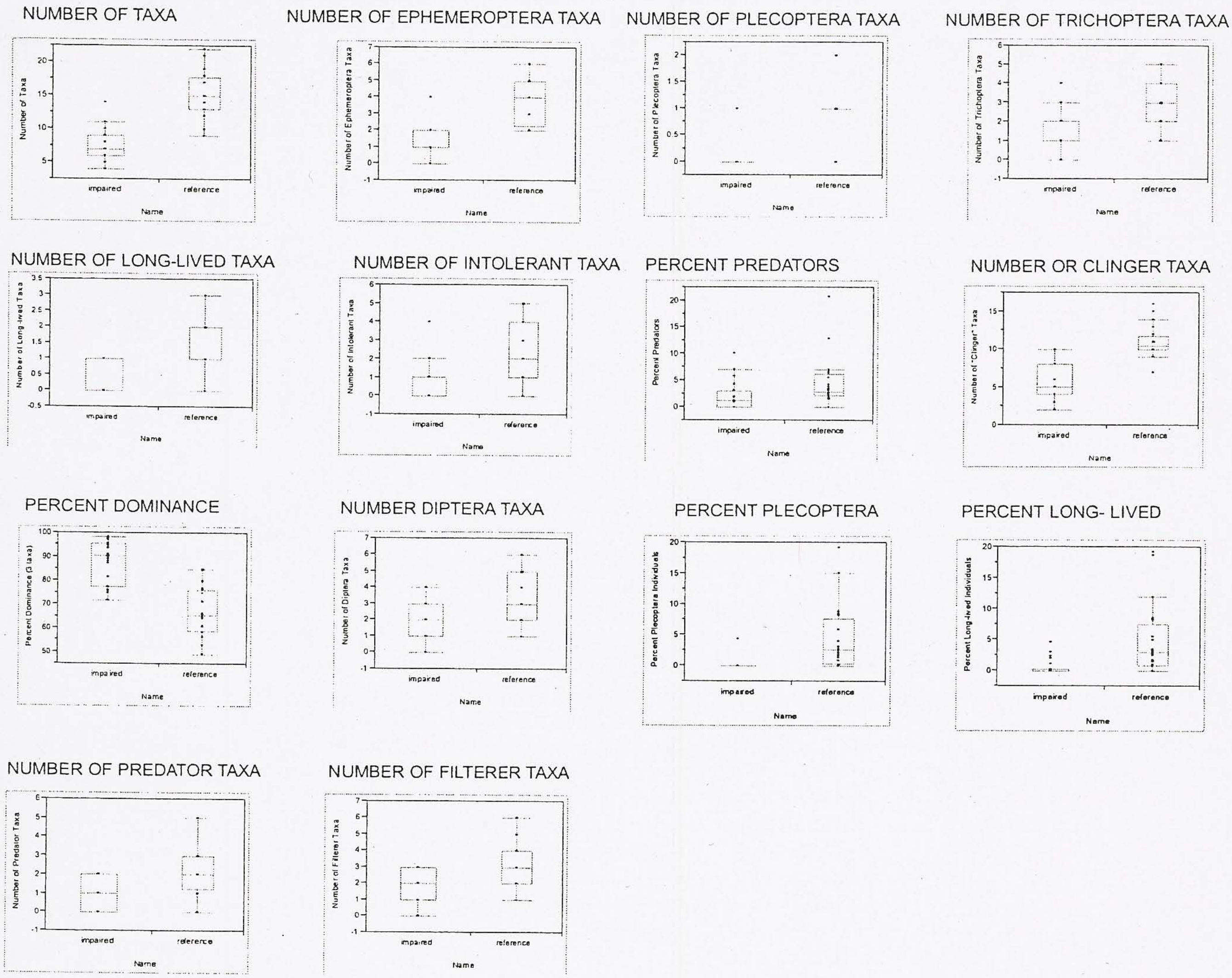
Table 4. Scoring Criteria for the 10 Standard and 4 Additional Metrics Included in the Benthic IBI

Metric	**0**	**5**	**10**
Percent Plecoptera	<6	6-12	>12
Percent Long-lived	<6	6-12	>12
Percent Predators	<6.5	6.5-13	>13
Number Taxa	0-6	7-12	>12
Number Plecoptera Taxa	0	1	>1
Number Trichoptera Taxa	0-1	2-3	>3
Number Long-lived Taxa	0	1	>1
Number Diptera Taxa	0-2	3-4	>4
Number Intolerant Taxa	0-1	2-3	>3
Number Filterer Taxa	0-2	3-4	>4
Alternate Metric			
Number Ephemeroptera Taxa	0-2	3-4	>4
Number Clinger Taxa	0-5	6-10	>10
Number Predator Taxa	0-1	2-3	>3
Percent Dominance	<15.5	15.5-31	>31

Table 5. Integrity Rating Categories for Benthic IBI Scores and General Invertebrate Community Characteristics for Each Category

Total BIBI Score	**Score with Alternates**	**Integrity Rating**	**Benthic Community Characteristics**
65-100	95-140	Excellent	This is the best situation; the community has been disturbed minimally by humans and there is a rich variety of taxa; >20 taxa are present; =15 Clinger taxa, =6 Diptera taxa, >5 Ephemeroptera taxa; <75% dominance.
50-60	65-90	Good	Slight impairment with a variety of taxa; =14 taxa present; =4 Diptera taxa present; usually <75% dominance.
30-45	40-60	Fair	Moderate impairment with modest variety of taxa; usually =10 taxa present; =2 Ephemeroptera and =2 Diptera taxa present; dominance variable around 75%.
10-25	15-35	Poor	High impairment with little variety of taxa; often only 5-9 taxa present; 1-2 Ephemeroptera taxa and 1-2 Diptera taxa; Gammarus usually present; >75% dominance.
0-5	0-10	Very Poor	Severe impairment; <5 taxa present; often high numbers of Gammarus; >90% dominance.

Figure 1. Quantile box plots of metrics that significantly discriminate between reference sites (n= 20) and impaired sites (n= 23) representing 25th and 75th quartiles as well as median values


NUMBER OF TAXA

NUMBER OF EPHEMEROPTERA TAXA

NUMBER OF PLECOPTERA TAXA

NUMBER OF TRICHOPTERA TAXA

NUMBER OF LONG-LIVED TAXA

NUMBER OF INTOLERANT TAXA

PERCENT PREDATORS

NUMBER OR CLINGER TAXA

PERCENT DOMINANCE

NUMBER DIPTERA TAXA

PERCENT PLECOPTERA

PERCENT LONG- LIVED

NUMBER OF PREDATOR TAXA

NUMBER OF FILTERER TAXA

B. Scoring of Metrics

Scoring for all 14 metrics is shown in Table 4. Percent Dominance was assigned reverse scoring. Each stream's B-IBI scores are the sum total of each individual metric score for that stream. The maximum score is 100 (excluding additional metrics) for excellent biotic integrity; including additional metrics, the maximum score is 140 for excellent biotic integrity. The lowest possible score is 0, indicating severe impairment and very poor biotic integrity. All ratings and general guidelines for benthic communities are presented in Table 5.

The 14 metrics, both required and additional, that make up the B-IBI show strong discrimination between reference and impaired sites. Both scoring strategies were tested between reference and impaired sites using a two sample t-test. The reference stream B-IBI scores (using the ten basic metrics for scoring) were significantly ($t = 9.74$, $p < 0.001$) higher (mean = 45.0) than the impaired site scores (mean = 11.5). Using all 14 total metrics, reference stream B-IBI scores also were significantly ($t = 9.84$, $p < 0.001$) higher (mean = 62.8) than the impaired site scores (mean = 15.2). All B-IBI scores for both reference and impaired sites were correlated significantly with values for all metrics as well (Table 6).

C. Description of Metrics

Metric 1: Total Number of Taxa

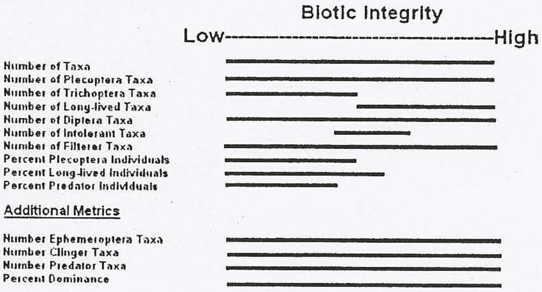
In many versions of the IBI, as well as other biomonitoring protocols, a decrease in total number of taxa is a sign of increasing stream impairment [2, 5, 6]. Total taxa richness can be affected by many factors including stream order, trophic status, and water quality [6]. A high diversity of taxa suggests there is plentiful niche space and food sources adequate enough to support the survival, both short-term and long-term, of multiple species [8]. This attribute is effective across the entire span of the scoring scale (Figure 2).

Metrics 2, 3, & 4: Number and Percent Plecoptera Taxa, and Number Trichoptera Taxa

Members of both Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa are a common indicator used in multimetric indices. These species are especially sensitive to decreased dissolved oxygen concentration in water, as well as increased concentrations of metals and organic compounds [9]. Therefore, with increased impairment, these species' presence will decrease. They are an exceptional indicator of pollution presence in a stream. Number of Plecoptera taxa is sensitive across the range of scores, and both percent Plecoptera individuals and number of Trichoptera Taxa are primarily sensitive in the bottom half of the scoring range (Figure 2).

Metrics 5 & 6: Number and Percent of Long-lived Taxa

Figure 2. Primary ranges of sensitivity for the 10 standard and 4 additional metrics included in the B-IBI for streams in southeastern Minnesota.



Long-lived taxa include several Plecoptera, Megaloptera, Arthropoda, and Mollusca species. These organisms have an extended life expectancy and depend on the vitality of their ecosystem to sustain their life cycle. An impaired system would lack the integrity to support these organisms, and therefore their presence decreases with an increase in human influence, making them a good indicator of stream impairment [10]. Number of Long-lived taxa was primarily sensitive in the upper half of the scoring system, whereas the percentage of this measure was effective in the lower half of the scoring scale (Figure 2).

Metrc 7: Number Diptera Taxa

Dipteran taxa are the true flies present in a stream environment. In this index, they were an extremely good discriminator between reference and impaired sites (Table 2). This attribute was also effective across the entire range of stream scores (Figure 2).

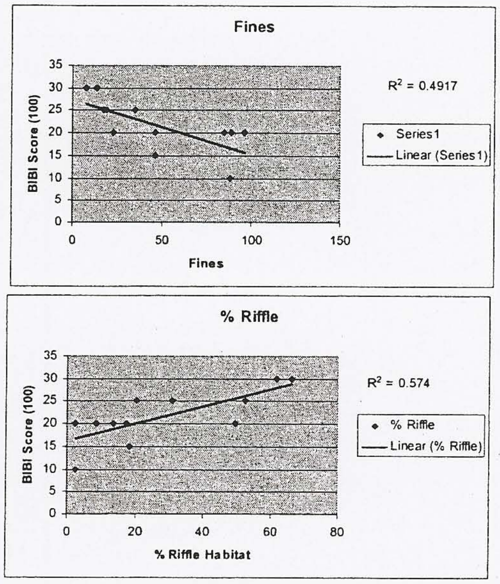


Figure 3: B-IBI Scores and their correlations with percent fines and percent riffle habitat for 12 validation sites from Garvin Brook and Whitewater River Systems.

Metric 8: Number Intolerant Taxa

Number of Intolerant Taxa is the only metric that remained in the tolerant and intolerants category after eliminating metrics. Intolerant species are those species which cannot withstand variations of conditions in their environment, and therefore are not present when their environment is altered from its natural condition. This metric was sensitive in the middle range of the scoring system (Figure 2).

Metrics 9 & 10: Number Filterer Taxa & Percent Predator Taxa

Both metrics here indicate different strategic feeding lifestyles. Filterer taxa are those species that feed by filtering out the organics from the water as their main source of nutrients. Most filterer species are Trichoptera or caddisflies. Predator taxa are those that depend on other invertebrates as their main source of nutrients. Most predator species are either Plecoptera or Dipteran species. The filterer metric is sensitive across the scoring range and the percent predator attribute is primarily sensitive in the lower half of the scoring range (Figure 2).

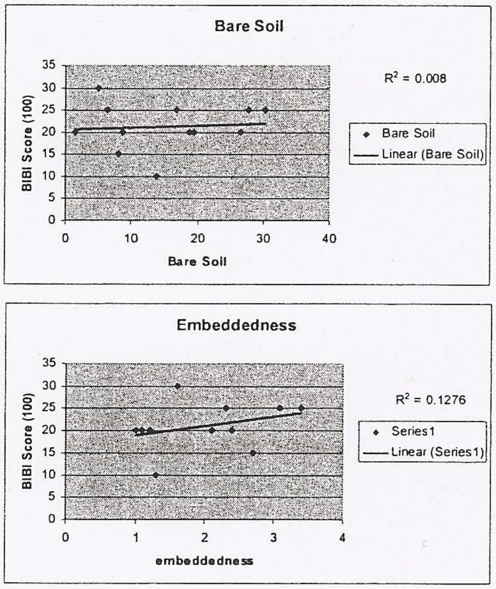


Figure 4: B-IBI Scores and their correlations with bare soil and embeddedness habitat for 12 validation sites from Garvin Brook and Whitewater River Systems.

Alternate Metric 1: Number Ephemeroptera Taxa

Ephemeroptera taxa (mayflies) are very pollution intolerant organisms [9]. Often paired with Trichoptera and Plecoptera taxa, the three serve as the commonly used EPT (Ephemeroptera, Plecoptera, Trichoptera) index [4, 6, 11]. This metric was highly correlated with total number of taxa (r= 0.828) yet was still included in the metric selections because of its strong ability to indicate streams with low dissolved oxygen levels and unnaturally elevated nutrient levels [9]. This attribute is effective across the entire range of the scoring scale (Figure 2).

Alternate Metric 2 & 3: Number Clinger Taxa & Number Predator Taxa

Number of clinger taxa and number of predator taxa are both metrics in the feeding and other habits category. Clinger taxa live clinging to various substrates as their means of survival. Most macroinvertebrates sampled in this study live clinger lifestyles. Predator taxa eat other invertebrates as their food source. Both of these attributes represented strong discrimina-

Table 6. Correlation Coefficients (Spearman r_s) Between Benthic IBI and Individual Metrics for Data from Reference and Impaired Sites (n= 43).

Metric (140)	r	P
# Clinger	0.925	<.0001
# Diptera	0.6182	<.0001
# Ephemeroptera	0.8581	<.0001
# Filterer	0.6222	<.0001
# Intolerant	0.6066	<.0001
# Long-lived	0.6717	<.0001
# Plecoptera	0.7199	<.0001
# Predator	0.6543	<.0001
# Taxa	0.9473	<.0001
# Trichoptera	0.6562	<.0001
% Dominance	-0.8652	<.0001
% Long-Lived	0.6618	<.0001
% Plecoptera	0.6816	<.0001
% Predator	0.4647	0.0017

Metric (100)	r	P
# Diptera	0.6342	<.0001
# Filterer	0.6147	<.0001
# Intolerant	0.6479	<.0001
# Long-lived	0.6676	<.0001
# Plecoptera	0.7266	<.0001
# Taxa	0.9312	<.0001
# Trichoptera	0.6667	<.0001
% Long-Lived	0.6635	<.0001
% Plecoptera	0.6987	<.0001
% Predator	0.4463	0.0027

tion between reference and impaired sites (Table 2) and were also sensitive across the entire range of the B-IBI scoring scale (Figure 2).

Alternate Metric 4: Percent Dominance

Percent dominance is the only metric in the population attributes category. It represents what percent of the entire invertebrate population is composed of the top three most abundant taxa present. Therefore, the higher percent dominance, the lower the variety of taxa present in the stream [12]. The metric is strongly negatively correlated with total B-IBI scores (r^2= 0.68) for each site. This attribute is sensitive across the entire scoring range (Figure 2).

B-IBI Validation:

The B-IBI score was significantly correlated with both the percent fines and percent riffle habitat measures in the 12 validation sites (Figure 3). The higher percent fines, the less invertebrate habitat present, and the lower B-IBI score; these measures are negatively correlated (r^2= -0.49) with one another. The higher the riffle habitat, the better invertebrate environment, the better the B-IBI score; these measures were positively correlated (r^2= 0.57) with one another. The B-IBI score was not correlated with bare soil or embeddedness habitat measures in the 12 validation sites (Figure 4). B-IBI scores for each validation site are reported in Table 7. The lowest scoring site for the Garvin Brook system (Rollingstone Creek, B-IBI= 10) and the lowest scoring site for the Whitewater River system (Logan Creek, B-IBI= 15) both run through agricultural land which accounts for their low scores.

Table 7. Validation Site Scores of Garvin Brook and Whitewater River Systems

Garvin Brook Site	B-IBI Score	Whitewater River Site	B-IBI Score
Upper	30	South Branch	30
Unnamed Creek	25	Carley State Park	20
Stockton Valley	20	Logan Creek	15
Stockton	20	North Branch	25
Lower	20	Middle Branch	30
Rollingstone Creek	10	Downstream	20

Discussion:

Many important findings resulted from the development of the Benthic Index of Biotic Integrity for streams in southeastern Minnesota. Several characteristics of invertebrate assemblages successful at discriminating between reference and impaired sites for other geographic locations also were successful in this region. The most successful attributes include total number of taxa, Plecoptera (stonefly) richness, Diptera (true fly) richness, Filterer taxa richness, Ephemeroptera (mayfly) richness, Clinger taxa richness, predator taxa richness, as well as percent dominance. All showed extremely strong discrimination between reference and impaired sites, and were all sensitive across the entire B-IBI scoring scale.

Some attributes were found to be ineffective in determining ecological health of streams in this region. Many of these are percentage metrics. It was much more beneficial in this scoring system to use numbers of different types of species rather than evaluating the percentages of individuals.

The final metrics included in the B-IBI covered the entire scale of the scoring system. For stream systems receiving high scores, at least five metrics are contributing information to the final score. In the mid-range of scores, at least seven metrics are sensitive. In the low ranging scores, eight metrics are contributing to the final score. When the four additional metrics are used, four more measures are contributing information to the final score because all four are sensitive across the entire range of the scoring system. This is important because if some ranges of scores do not have metrics sensitive there, the scoring system is not effective.

Both percent riffle and percent fines habitat variables correlated with the scoring system, logically. The higher percent fines, the less invertebrate habitat present, and the lower B-IBI score. If the riffle habitat is stronger, the invertebrate environment is better, and the better the B-IBI scores. Even though both correlated around 0.50, only twelve sites were used to validate the scoring system, and this shows a strong relationship. The bare soil variable measured the amount of erosion occurring on the shoreline of the site. This measure probably did not correlate with the B-IBI scores because it would have an effect on a downstream site condition rather than a site directly affiliated with that shoreline. The embeddedness measure did not correlate with the scoring system, and it is unknown why it did not. It would probably be useful to validate the effectiveness of this B-IBI by comparing it with a different scoring system that has already been developed.

Conclusion:

In conclusion, the Benthic Index of Biotic Integrity is an effective measure to determine the health of streams in southeastern Minnesota. Metrics included in the system discriminate between reference and impaired sites, and cover the entire range of the scoring scale. The scoring system correlates significantly and logically with different habitat indicators.

The B-IBI is simple to use and hopefully will benefit stream researchers in identifying and diagnosing the effects of human influences on streams in this region in the future.

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